Preface (added April 2003)

Note: *The KFM, A Homemade Yet Accurate and Dependable Fallout Meter,* was published by Oak Ridge National Laboratory report in1979. Some of the materials originally suggested for suspending the leaves of the Kearny Fallout Meter (KFM) are no longer available. Because of changes in the manufacturing process, other materials (e.g., sewing thread, unwaxed dental floss) may not have the insulating capability to work properly. Oak Ridge National Laboratory **has not tested** any of the following suggestions, but they have been used by other groups. When using these instructions, the builder can verify the insulating ability of his materials by checking the leakage rate and comparing it to the author's leakage tests.

- The principal author, Cresson Kearny, updated his instructions after his retirement from ORNL in Appendix C of an 1987 edition of *Nuclear War Survival Skills*[1] to include two suggestions for thin monofilament fishing line and narrow strips of dry cleaning bags:

  > "Very thin monofilament fishing line or leader is an excellent insulator. The 2-pound- test strength, such as DuPont's 'Stren' monofilament fishing line, is best. 'Trilene' 2-pound "nylon leader" a monofilament manufactured by Berkley and Company, also is excellent. (A 4-pound monofilament line will serve, but is disadvantageously stiff.) Some modern monofilament lines or leaders such as 'Trilene' contain an additive that makes them pliant, but also makes them poorer insulators for the first several hours after being taken out of their dispenser and used to suspend the leaves of a KFM. However, in about 6 hours the silica gel or anhydrite drying agent in a KFM removes this additive and the monofilament becomes as good an insulator as an even strands of unwaxed dental floss" [tested dental floss no longer available].
  >
  > "To minimize the chance of using a piece of monofilament or other thread that has been soiled and thus changed into a poor insulator, always first remove and discard the outermost layer of thread on any spool that has not been kept clean in a plastic bag or other packaging after being initially unwrapped.
  >
  > "...most American homes have an excellent insulator, very thin polyethylene film—especially clean dry cleaners' bags. A narrow insulating strip cut only 1/16 inch wide can be used to suspend each KFM leaf, instead of an insulating thread. (Installed leaves suspended on strips of thin plastic film must be handled with care.)
  >
  > "To cut 1/16-inch-wide strips from very thin polyethylene film, first cut a piece about 6 x 10 inches. Tape only the two 6-inch-wide ends to a piece of paper (such as a brown grocery bag), so that the film is held flat and smooth on the paper. Make 10 marks. 1/16 inch apart, on each of the two tapes that are holding the film. Place a light so that its reflection on the film enables you to see the edge of the film that you are preparing to

[1]URL: http://www.oism.org/nwss/ (accessed Mar. 4, 2003).

cut. Then use a very sharp, clean knife or clean razor blade, guided by the edge of a firmly held ruler, to cut nine strips, of which you will select the best two. When cutting, hold the knife almost horizontal, with the plane of its blade perpendicular to the taped-down film. Throughout this procedure avoid touching the center parts of the strips."[2]

- A Utah teacher, who uses the Kearny Fallout Meter, in teaching about radiation, has found that strands of clean human hair (cleaned with shampoo or alcohol) can be used as an alternative suspension system[3].

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[2]New material only: Copyright (c) 1986 by Cresson H. Kearny. "The copyrighted material may be reproduced without obtaining permission from anyone, provided: (1) all copyrighted material is reproduced full-scale (except for microfiche reproductions), and (2) the part of this copyright notice within quotation marks is printed along with the copyrighted material."

[3]Dr. Paul Lombardi, URL: http://www.sdavjr.davis.k12.ut.us/~paul/radiatio.htm (accessed Mar. 4, 2003.)

ORNL DWG 72-8203

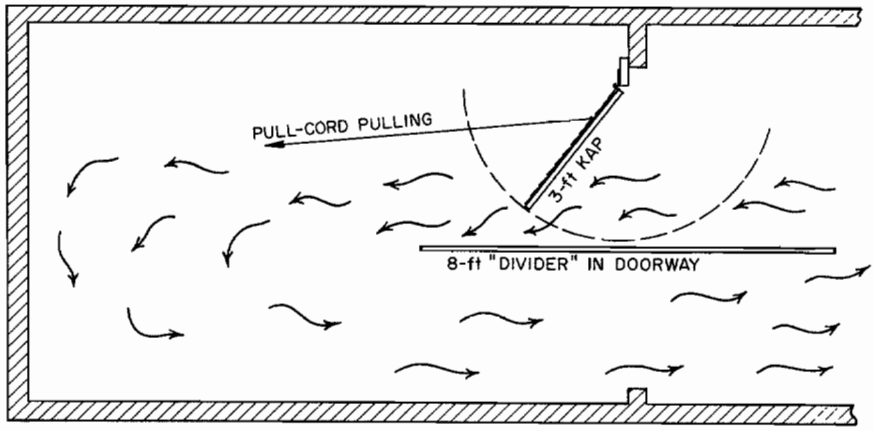


Fig. 27. Use of a "divider" to ventilate a shelter with only one opening.

F. Installing a KAP in a Steel-Framed Doorway

If you need to install a KAP in a steel-framed doorway and it is not feasible to screw or otherwise permanently connect it to the doorway, you can attach the KAP by using a few boards and some cord, as illustrated by Figs. 28 and 29. The two horizontal boards shown extending across the doorway are squeezed tightly against the two sides of the wall in which the doorway is located by tightening two loops of cord, one near each side of the doorway. One loop is illustrated. A cord is first tightened around the two horizontal boards. Then the looped cord is further tightened by binding it in the center with another cord, as illustrated.

Two large "C" clamps serve even better than two looped cords. However, secure support for a swinging KAP still requires the use of a vertical support board on each side of the doorway, as illustrated.

ORNL DWG 72-6364

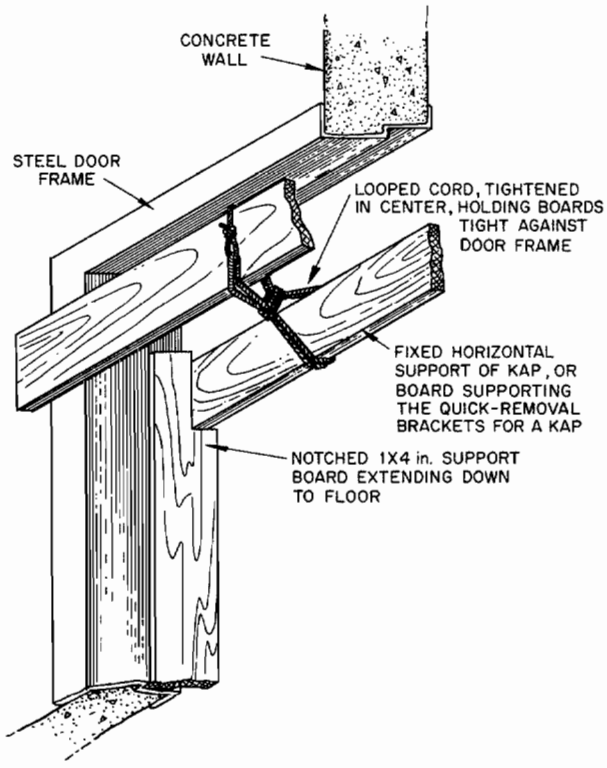


Fig. 28.

Figure 29 shows a quick-removal bracket supported by two horizontal boards tightened across the upper part of a doorway by looped cords, as described above. Also, study Fig. 19 and its accompanying instructions.

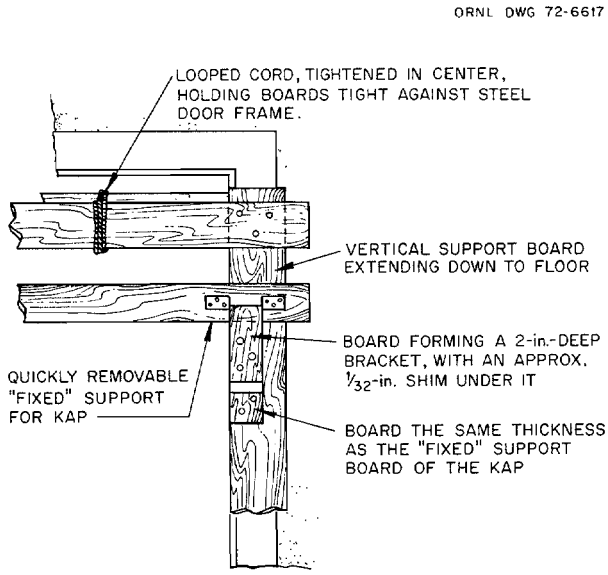


Fig. 29.

G. Building More Durable KAPs

If you are building KAPs in normal times, you may want to use materials that will make your pumps last longer, even though these materials are more difficult to obtain and are more expensive.

Durability tests have shown that the KAP parts that wear out first are the flaps and the pulleys. In 6-ft KAPs, the lower flaps are subject to hard use. Lower flaps made of 6-oz (per sq. yd), clear, nylon-reinforced, plied vinyl have lasted undamaged for over 1000 hours of full-stroke pumping, without having their edges reinforced. Lower flaps made of 6-mil nylon-reinforced polyethylene, without edge reinforcements, have lasted for 1000 hours with only minor damage.

The best pulley tested was a marine pulley such as that used on small sailboats, with a Delrin (DuPont) 2-in.-diameter wheel and $^3/_{16}$-in. stainless steel shaft. This pulley was undamaged after operating a 6-ft KAP for 324 hours. The pulley appeared to be good for hundreds of hours of further operation.

The best pulley-cords tested were of braided dacron or nylon.

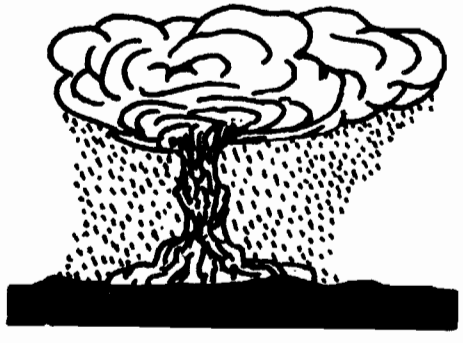
H. Using Air Filters

To supply shelter occupants with filtered air usually would be of **much less** importance to their survival and health than to provide them with adequate volumes of outdoor air to maintain tolerable temperatures. However, filtering the entering air could prove worthwhile, provided:

- Your shelter is not in an area likely to be subjected to blast, or it is a blast shelter with blast doors and blast valves protecting everything inside.
- Work on filters is started *after* you have completed more essential work, including the building of a high-protection-factor shelter, making, installing, and testing the necessary number of KAPs, storing adequate water, making a homemade fallout meter, etc.
- You have enough low-resistance filters (such as fiberglass dust filters used in furnaces and air-conditioners) and other materials for building the necessary large, supported filter in front of your KAP.
- Your KAP can pump an adequate volume of air through the filter and shelter.
- The filter is installed so that it can be easily removed if shelter temperatures rise too high.

To prevent a filter used with a KAP from causing too great a reduction in the volume of air that the KAP can pump through your shelter, you must use **large areas of low-resistance filter material.** An example: In one ventilation test, a large basement shelter was used which had two ordinary doorways at its opposite ends. These served as its air-intake and its air-exhaust openings. A 72×29 in. KAP operating in one doorway pumped almost 5000 cubic feet per minute through the shelter. But when a filter frame holding 26 square feet of 1-in.-thick fiberglass dust filters was placed across the air-intake stairwell, the KAP could pump only about 3400 cfm through this filter and the shelter.

APPENDIX C



A HOMEMADE FALLOUT METER, THE KFM
HOW TO MAKE AND USE IT

FOLLOWING THESE INSTRUCTIONS MAY SAVE YOUR LIFE

The complete KFM instructions include patterns to be cut out and used to construct the fallout meter. At the end of the instructions are extra patterns on 4 unnumbered pages. The reader is urged to use these extra patterns to make KFM's in normal peacetime and to keep the complete instructions intact for use during a recognized crisis period.

If Xerox copies of the patterns are used, they should be checked against the originals in order to correct a few of the small changes in size that usually result from the copying process. Xerox copies of all the KFM patterns are satisfactory provided: (1) on the PAPER PATTERN TO WRAP AROUND KFM CAN, the distances between the 4 marks for the HOLES FOR STOP-THREAD are corrected--to eliminate the lengthening caused by xerox-type duplication; and (2) the dimensions of the FINISHED-LEAF PATTERN are corrected.

These instructions, including the heading on this page and the illustrative photos, can be photographed without additional screening and rapidly reproduced by a newspaper or printer. If you keep the KFM instructions intact, during a worsening crisis you may be able to use them to help your friends and thousands of your fellow citizens by making them available for reproduction.

I. The Need for Accurate and Dependable Fallout Meters

If a nuclear war ever strikes the United States, survivors of the blast and fire effects would need to have reliable means of knowing when the radiation in the environment around their shelters had dropped enough to let them venture safely outside. Civil defense teams could use broadcasts of surviving radio stations to give listeners a general idea of the fallout radiation in some broadcast areas. However, the fallout radiation would vary widely from point to point and the measurements would be made too far from most shelters to make them accurate enough to use safely. Therefore, each shelter should have some dependable method of measuring the changing radiation dangers in its own area.

During a possible nuclear crisis that was rapidly worsening, or after a nuclear attack, most unprepared Americans could not buy or otherwise obtain a fallout meter -- an instrument that would greatly improve their chances of surviving a nuclear war. The fact that the dangers from fallout radiation -- best expressed in terms of the radiation dose rate, roentgens per hour (R/hr) -- quite rapidly decrease during the first few days, and then decrease more and more slowly, makes it very important to have a fallout meter capable of accurately measuring the unseen, unfelt and changing fallout dangers. Occupants of a fallout shelter should be able to control the radiation doses they receive. In order to effectively control the radiation doses, a dependable measuring instrument is needed to determine the doses they receive while they are in the shelter and while they are outside for emergency tasks, such as going out to get badly needed water. Also, such an instrument would permit them to determine when it is safe to leave the shelter for good.

Untrained families, guided only by these written instructions and using only low cost materials and tools found in most homes, have been able to make a KFM by working 3 or 4 hours. By studying the operating sections of these instructions for about 1 ½ hours, average untrained families have been able to successfully use this fallout meter to measure dose rates and to calculate radiation doses received, permissible times of exposure, etc.

The KFM (Kearny Fallout Meter) was developed at Oak Ridge National Laboratory. It is understandable, easily repairable, and as accurate as most civil defense fallout meters. In the United States in 1979 a commercially available, dependable fallout meter that has as high a range as a KFM for radiation dose-rate measurements retailed for around $1000.

Before a nuclear attack occurs is the best time to build, test and learn how to use a KFM. However, this instrument is so simple that it could be made even after fallout arrives **provided** that all the materials and tools needed (see lists given in Sections V, VI, and VII) and a copy of these instructions have been carried into the shelter.

II. Survival Work Priorities During a Crisis

Before building a KFM, persons expecting a nuclear attack within a few hours or days and already in the place where they intend to await attack should work with the following priorities: (1) build or improve a high-protection-factor shelter (if possible, a shelter covered with 2 or 3 feet of earth and separate from flammable buildings). At the same time, make and install a KAP (a homemade shelter-ventilating pump) -- if instructions and materials are available. Also store at least 15 gallons of water for each shelter occupant -- if containers are available. (2) Assemble all materials for one or two KFM's. (3) Make and store the drying agent (by heating wallboard gypsum, as later described) for both the KFM and its dry-bucket.

III. How to Use These Instructions to Best Advantage

1. Read ALOUD all of these instructions **through Section VII,** "Tools Needed," before doing anything else.

2. Next assemble all of the needed materials and tools.

3. Then read ALOUD ALL of each section following Section VII before beginning to make the part described in that section.

   A FAMILY THAT FAILS TO READ ALOUD ALL OF EACH SECTION DESCRIBING HOW TO MAKE A PART, BEFORE BEGINNING TO MAKE THAT PART, WILL MAKE AVOIDABLE MISTAKES AND WILL WASTE TIME.

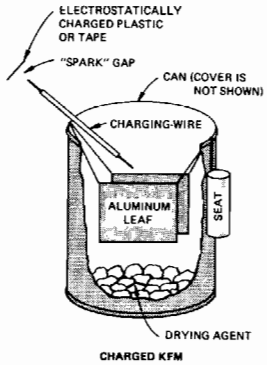
4. Have different workers, or pairs of workers, make the parts they are best qualified to make. For example, a less skilled worker should start making the drying agent (as described in Section VIII) before other workers start making other parts. The most skilled worker should make and install the aluminum-foil leaves (Sections X and XI).

5. Give workers the sections of the instructions covering the parts they are to build--so they can follow the step-by-step instructions, checking off with a pencil each step as it is completed.

6. Discuss the problems that arise. The head of the family often can give better answers if he first discusses the different possible interpretations of some instructions with other family members, including teenagers.

7. After completing one KFM and learning to use it, if time permits make a second KFM--that should be a better instrument.

IV. What a KFM Is and How It Works

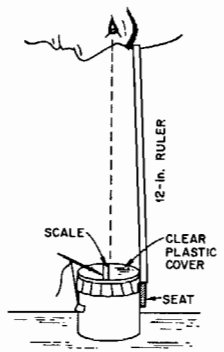


CHARGED KFM

A KFM is a simple electroscope fallout meter with which fallout radiation can be measured accurately. To use a KFM, an electrostatic charge must first be placed on its **two** separate aluminum-foil leaves. These leaves are insulated by being suspended separately on clean, dry insulating threads.

To take accurate readings, the air inside a KFM must be kept very dry by means of drying agents such as dehydrated gypsum (easily made by heating gypsum wallboard, "sheetrock") or silica gel. (Do not use calcium chloride or other salt.) Pieces of drying agent are placed on the bottom of the ionization chamber (the housing can) of a KFM.

An electrostatic charge is transferred from a homemade electrostatic charging device to the two aluminum-foil leaves of a KFM by means of its charging-wire. The charging-wire extends out through the transparent plastic cover of the KFM.



When the two KFM leaves are charged electrostatically, their like charges (both positive or both negative) cause them to be forced apart. When fallout radiations (mainly gamma rays, that are similar to X rays but more energetic) penetrate the can and strike the air inside the can, they produce charged ions in this enclosed air. The covered can is an ionization chamber. These enclosed charged ions cause part or all of the electrostatic charge on the aluminum-foil leaves to be discharged. As a result of losing charge, the two KFM leaves move closer together.

To read the separation of the **lower** edges of the two KFM leaves with one eye, look straight down on the leaves and the scale on the clear plastic cover. Keep the reading eye 12 inches above the SEAT. The KFM should be resting on a horizontal surface. To be sure the reading eye is always at this exact distance, place the lower end of a 12-inch ruler on the SEAT, while the upper end of the ruler touches the eyebrow above the reading eye. It is best to hold the KFM can with one hand and the ruler with the other. Using a flashlight makes the reading more accurate.

If a KFM is made with the specified dimensions and of the specified materials, its accuracy is automatically and permanently established. Unlike most radiation measuring instruments, a KFM never needs to be calibrated or tested with a radiation source, if made and maintained as specified and used with the following table that is based on numerous calibrations made at Oak Ridge National Laboratory.

The millimeter scale is cut out and attached (see photo illustrations on the following page) to the clear plastic cover of the KFM so that its zero mark is directly above the two leaves in their discharged position when the KFM is resting on a horizontal surface. A reading of the separation of the leaves is taken by noting the number of millimeters that the **lower edge** of one leaf appears to be on, on one side of the zero mark on the scale, and almost at the same time noting the number of millimeters the **lower edge** of the other leaf appears to be on, on the other side of the zero mark. The **sum** of these two apparent positions of the lower edges of the two leaves is called a KFM reading. The drawing appearing after the photo illustrations shows the **lower** edges of the leaves of a KFM appearing to be 9 mm on the right and zero and 10 on the left, giving a KFM reading of 19 mm. (Usually the lower edges of the leaves are not at the same distance from the zero mark.)

As will be fully explained later, the radiation dose rate is determined by:

1. charging and reading the KFM before exposure;
2. exposing it to radiation for a specified time in the location where measurement of the dose rate is needed -- when outdoors, holding the KFM about 3 ft. above the ground;
3. reading the KFM after its exposure;
4. calculating, by subtraction, the **difference** between the reading taken before exposure and the reading taken after exposure;
5. using this table to find what the dose rate was during the exposure -- as will be described later.

TABLE USED TO FIND DOSE RATES (R/HR) FROM KFM READINGS

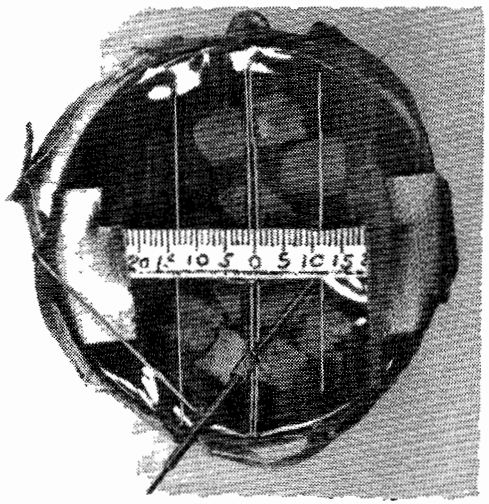
**DIFFERENCE BETWEEN THE READING BEFORE EXPOSURE AND THE READING AFTER EXPOSURE (8-PLY STANDARD-FOIL LEAVES)*

DIFF.* IN READINGS	TIME INTERVAL OF AN EXPOSURE				
	15 SEC. R/HR	1 MIN. R/HR	4 MIN. R/HR	16 MIN. R/HR	1 HR. R/HR
2 mm	6.2	1.6	0.4	0.1	0.03
4 mm	12.	3.1	0.8	0.2	0.06
6 mm	19.	4.6	1.2	0.3	0.08
8 mm	25.	6.2	1.6	0.4	0.10
10 mm	31.	7.7	2.0	0.5	0.13
12 mm	37.	9.2	2.3	0.6	0.15
14 mm	43.	11.	2.7	0.7	0.18

Instructions on how to use a KFM are given after those detailing how to make and charge this fallout meter.

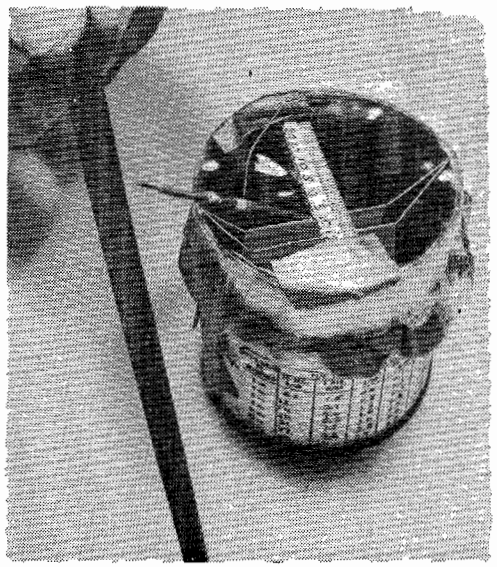
To get a clearer idea of the construction and use of a KFM, look carefully at the following photos and read their captions.

A. An Uncharged KFM. The charging wire has been pulled to one side by its adjustment-thread. This photo was taken looking straight down at the upper edges of the two flat, 8-ply aluminum leaves. At this angle the leaves are barely visible, hanging vertically side by side directly under the zero mark, touching each other and with their ends even. Their suspension-threads insulate the leaves. These threads are almost parallel and touch (but do not cross) each other where they extend over the top of the rim of the can.



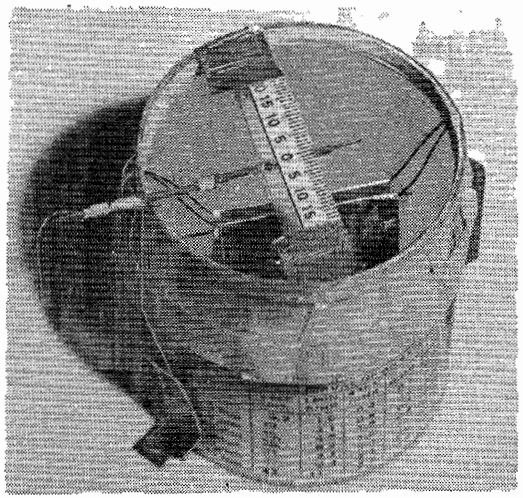
B. Charging a KFM by a Spark-Gap Discharge from a Tape That Has Been Electrostatically Charged by Being Unwound Quickly. Note that the charged tape is moved so that its surface is perpendicular to the charging-wire.

The high-voltage electrostatic charge on the unwound tape (that is an insulator) jumps the spark-gap between the tape and the upper end of the charging-wire, and then flows down the charging-wire to charge the insulated aluminum-foil leaves of the KFM. (Since the upper edges of the two leaves are ¾ inch below the scale and this is a photo taken at an angle, both leaves appear to be under the right side of the scale.)



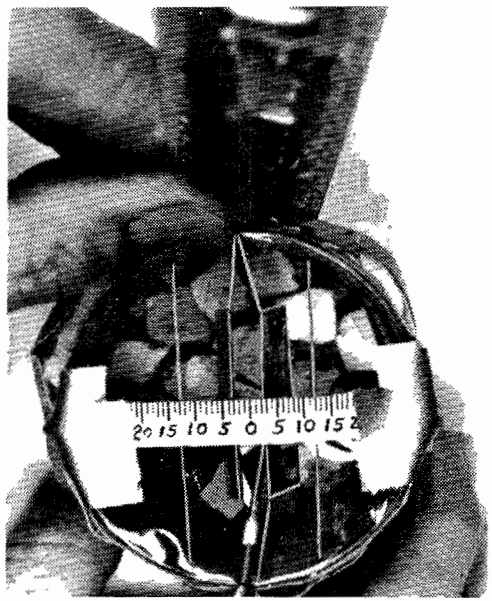
C. A Charged KFM. Note the separation of the upper edges of its two leaves. The charging-wire has been raised to an almost horizontal position so that its lower end is too far above the aluminum leaves to permit electrical leakage from the leaves back up the charging-wire and into the outside air.

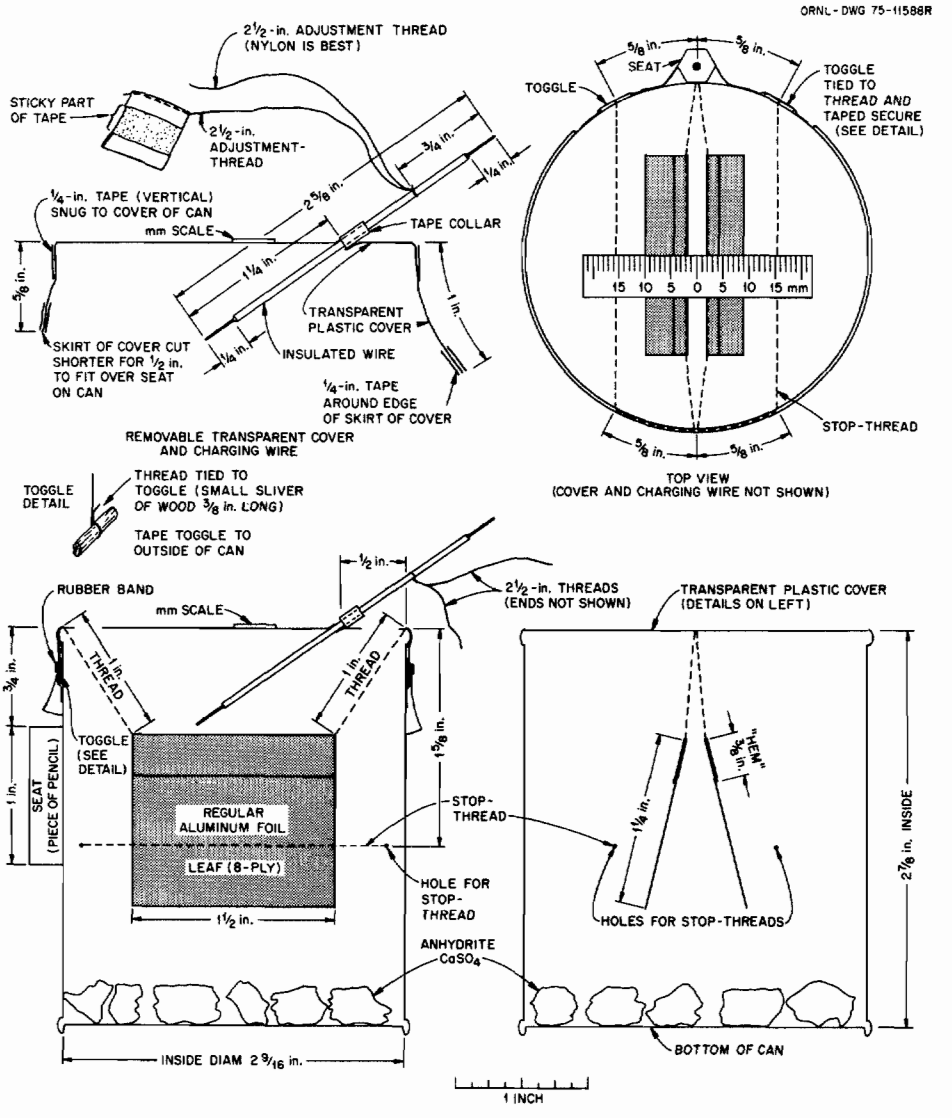
Also note the SEAT, a piece of pencil taped to the right side of the can, opposite the charging wire.



D. Reading a KFM. A 12-inch ruler rests on the SEAT and is held vertical, while the reader's eyebrow touches the upper end of the ruler. The lower edge of the right leaf is under 8 on the scale and the lower edge of the left leaf is under 6 on the scale, giving a KFM reading of 14.

For accurate radiation measurements, a KFM should be placed on an approximately horizontal surface, but the charges on its two leaves and their displacements do not have to be equal.





(This is not a Full Scale Drawing).

V. **Materials Needed**

A. For the KFM: (In the following list, when more than one alternative material is given, the **best** material is listed first.)

1. Any type metal can, approximately 2-9/16 inches in diameter inside and 2-7/8 inches high inside, washed clean with soap. (This is the size of a standard 8-ounce can. Since most soup cans, pop cans, and beer cans also are about 2-9/16 inches in diameter inside, the required size of can can also be made by cutting down the height of more widely available cans -- as described in Section IX of these instructions.)

2. Standard aluminum foil -- 2 square feet. (In 1977, 2 square feet of a typical American aluminum foil weighed about 8.2 grams -- about 0.29 oz.) (If only "Heavy Duty" or "Extra Heavy Duty" aluminum foil is available, make 5-ply leaves rather than 8-ply leaves of standard foil; the resultant fallout meter will be almost as accurate.)

3. Doorbell-wire, or other light insulated wire (preferably but not necessarily a single-strand wire inside the insulation) -- 6 inches.

4. Any type of lightweight thread (preferably but not necessarily nylon). (Best is twisted nylon thread; next best, **unwaxed** lightweight nylon dental floss; next best, silk; next best, polyester.) -- 3 feet. (Thread should be **CLEAN**, preferably not having been touched with fingers. Monofilament nylon is too difficult to see, handle, and mark.)

5. A piece of clear plastic -- a 6 x 6 inch square. Clear vinyl (4 mils thick) used for storm-proofing windows is best, but any reasonably stout and rather clear plastic will serve. The strong clear plastic used to wrap pieces of cheese, if washed with hot water and soap, is good. Do not use weak plastic or cellophane.

6. Cloth duct tape ("silver tape"), or masking tape, or freezer tape, or Scotch-type tape -- about 10 square inches. (Save at least 10 feet of Scotch Magic Transparent Tape for the charging device.)

7. Band-Aid tape, or masking tape, or freezer tape, or Scotch transparent tape, or other thin and very flexible tapes -- about 2 square inches.

8. Gypsum wallboard (sheetrock) -- about 1/2 square foot, best about 1/2 inch thick. (To make the essential drying agent.)

9. Glue -- not essential, but useful to replace Band-Aid and other thin tapes. "One hour" epoxy is best. Model airplane cement is satisfactory.

10. An ordinary wooden pencil and a small toothpick (or split a small sliver of wood).

11. Two strong rubber bands, or string.

12. Several small, transparent plastic bags, such as sandwich bags, to cover the KFM when it is exposed where fallout particles may get on it and contaminate it. Or pieces of thin, transparent plastic film, such as that from bread bags. Also small rubber bands, or string.

B. For the Charging Devices:

1. Most hard plastic rubbed on **dry** paper. This is the best method.

   a. Plexiglas and most other hard plastics, such as are used in draftsmen's triangles, common smooth plastic rulers, etc. -- at least 6 inches long.

   b. **Dry** paper -- **Smooth** writing or typing paper. Tissue paper, newspaper, or facial tissue such as Kleenex, or toilet paper are satisfactory for charging, but not as durable.

2. Scotch Magic Transparent Tape (3/4 inch width is best), or Scotch Transparent Tape, or P.V.C. (Polyvinyl chloride) insulating electrical tapes, or a few of the other common brands of Scotch-type tapes. (Some plastic tapes do not develop sufficiently high-voltage electrostatic charges when unrolled quickly.) This method cannot be used for charging a KFM inside a dry-bucket, needed for charging when the air is very humid.

C. For Determining Dose Rates and Recording Doses Received:

1. A watch -- preferably with a second hand.

2. A flashlight or other light, for reading the KFM in a dark shelter or at night.

3. Pencil and paper -- preferably a notebook.

D. For the Dry-Bucket: (A KFM must be charged inside a dry-bucket if the air is very humid, as it often is inside a crowded, long-occupied shelter lacking adequate forced ventilation.)

1. A large bucket, pot, or can, preferably with a top diameter of at least 11 inches.

2. Clear plastic (best is 4-mil-thick clear plastic used for storm windows). A square piece 5 inches wider on a side than the diameter of the bucket to be used.

3. Cloth duct tape, one inch wide and 8 feet long (or 4 ft., if 2 inches wide). Or 16 ft. of freezer tape one inch wide.

4. Two plastic bags 14 to 16 inches in circumference, such as ordinary plastic bread bags. The original length of these bags should be at least 5 inches greater than the height of the bucket.

5. About one square foot of wall board (sheetrock), to make anhydrite drying agent.

6. Two 1-quart Mason jars or other airtight containers, one in which to store anhydrite and another in which to keep dry the KFM charging devices.

7. Strong rubber bands -- enough to make a loop around the bucket. Or string.

VI. **Useful but not Essential Materials**

--Which Could be Obtained Before a Crisis--

1. An airtight container (such as a large peanut butter jar) with a mouth at least 4 inches wide, in which to keep a KFM, along with some drying agent, when it is not being used. Keeping a KFM very dry greatly extends the time during which the drying agent **inside** the KFM remains effective.

2. Commercial anhydrite with a color indicator, such as the drying agent Drierite. This granular form of anhydrite remains light blue as long as it is effective as a drying agent; it turns pink when it becomes ineffective. Heating in a hot oven or in a can over a fire reactivates it as a drying agent and restores its light blue color. Obtainable from laboratory supply sources.

3. Four square feet of aluminum foil, to make a moisture-proof cover for the dry-bucket.

VII. **Tools Needed**

Small nail - sharpened
Stick, or a wooden tool handle
(best 2-2½ inch diameter and at least 12 inches long)
Hammer
Pliers
Scissors
Needle - quite a large sewing needle, but less than 2½ inches long
Knife with a small blade -- sharp
Ruler (12 inches)

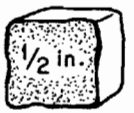
VIII. **Make the Drying Agent**

-- The Easiest Part to Make, but Time Consuming --

1. For a KFM to measure radiation accurately, the air inside its ionization chamber must be kept **very dry**. An excellent drying agent (anhydrite) can be made by heating the gypsum in ordinary gypsum wallboard (sheetrock). Do NOT use calcium chloride.

2. Take a piece of gypsum wallboard approximately 12 inches by 6 inches, and preferably with its gypsum about 3/8 inches thick. Cut off the paper and glue, easiest done by first wetting the paper. [Since water vapor from normal air penetrates the plastic cover of a KFM and can dampen the anhydrite and make it ineffective in as short a time as two days, fresh batches of anhydrite must be made before the attack and kept ready inside the shelter for replacement. The useful life of the drying agent inside a KFM can be greatly lengthened by keeping the KFM inside an airtight container (such as a peanut butter jar with a 4-inch-diameter mouth) with some drying agent, when the KFM is not being used.]

3. Break the white gypsum filling into small pieces and make the largest no more than 1/2 in. across. (The tops of pieces larger than this may be too close to the aluminum foil leaves.) If the gypsum is dry, using a pair of pliers makes breaking it easier. Make the largest **side** of the largest pieces no bigger than this.



4. Dry gypsum is **not** a drying agent. To drive the water out of the gypsum molecules and produce the drying agent (anhydrite), heat the gypsum in an oven at its **highest** temperature (which should be above 400 degrees F) for one hour. Heat the gypsum after placing the small pieces no more than two pieces deep in a pan. Or heat the pieces over a fire for 20 minutes or more in a pan or can heated to a dull red.

5. If sufficient aluminum foil and time are available, it is best to heat the gypsum and store the anhydrite as follows:

   a. So that the right amount of anhydrite can be taken quickly out of its storage jar, put enough pieces of gypsum in a can with the same diameter as the KFM, measuring out a batch of gypsum that almost covers the bottom of the can with a single layer.

   b. Cut a piece of aluminum foil about 8 in. x 8 in. square, and fold up its edges to form a bowl-like container in which to heat one batch of gypsum pieces.

   c. Measure out 10 or 12 such batches, and put each batch in its aluminum foil "bowl."

   d. Heat all of these filled "bowls" of gypsum in hottest oven for one hour.

e. As soon as the aluminum foil is cool enough to touch, fold and crumple the edges of each aluminum foil "bowl" together, to make a rough aluminum-covered "ball" of each batch of anhydrite.

f. Promptly seal the batches in airtight jars or other airtight containers, and keep containers closed except when taking out an aluminum-covered "ball."

6. Since anhydrite absorbs water from the air very rapidly, quickly put it in a **dry** airtight container while it is still quite hot. A Mason jar is excellent.

7. To place anhydrite in a KFM, drop in the pieces one by one, being careful not to hit the leaves or the threads. The pieces should almost cover the bottom of the can, with no piece on top of other pieces.

8. To remove anhydrite from a KFM, it is best to use a pair of scissors or tweezers as forceps, holding them in a vertical position and not touching the leaves. Or carefully pour the anhydrite out of the can while with your forefinger and thumb you carefully hold the aluminum leaves out of the way. Avoid touching threads.

IX. **Make the Ionization Chamber of the KFM**

(To Avoid Mistakes and Save Time,
Read All of This Section ALOUD Before Beginning Work.)

1. Remove the paper label (if any) from an ordinary 8-ounce can from which the top has been smoothly cut. Wash the can with soap and water and dry it. (An 8-ounce can has an inside diameter of about 2-9/16 inches and an inside height of about 2-7/8 inches.)

2. Skip to step 3 if an 8-ounce can is available. If an 8-ounce can is not available, reduce the height of any other can having an inside diameter of about 2-9/16 inches (such as most soup cans, most pop cans, or most beer cans). To cut off the top part of a can, first measure and mark the line on which to cut. Then to keep from bending the can while cutting, wrap newspaper tightly around a stick or a round wooden tool handle, so that the wood is covered with 20 to 30 thicknesses of paper and the diameter (ideally) is only slightly less than the diameter of the can.

   One person should hold the can over the paper-covered stick while a second person cuts the can little by little along the marked cutting line. If leather gloves are available, wear them. To cut the can off smoothly, use a file, or use a hacksaw drawn backwards along the cutting line. Or cut the can with a sharp, short blade of a pocketknife by: (1) repeatedly stabbing downward vertically through the can into the paper, and (2) repeatedly making a cut about 1/4 inch long by moving the knife into a sloping position, while keeping its point still pressed into the paper covering the stick.

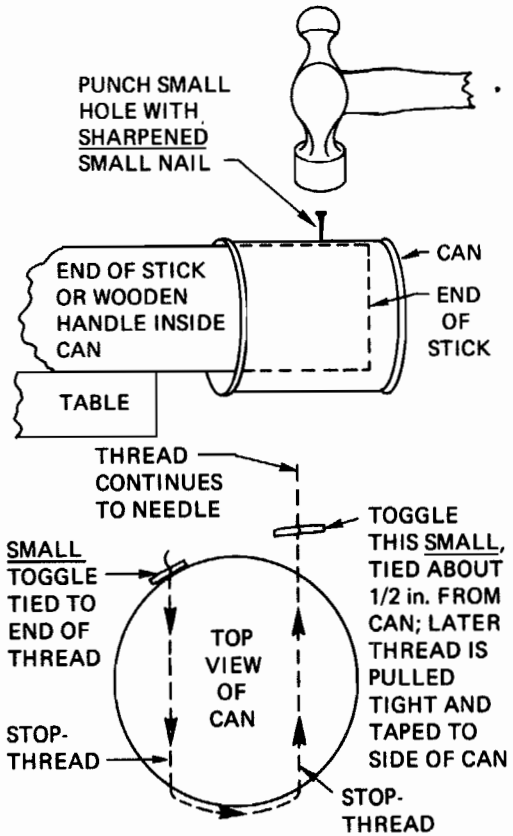
   Next, smooth the cut edge, and cover it with small pieces of freezer tape or other flexible tape.

3. Cut out the PAPER PATTERN TO WRAP AROUND KFM CAN. (Cut one pattern out of the following Pattern Page A.) Glue (or tape) this pattern to the can, starting with one of the two short sides of the pattern. Secure this starting short side directly over the side seam of the can. Wrap the pattern snugly around the can, gluing or taping it securely as it is being wrapped. (If the pattern is too wide to fit flat between the rims of the can, trim a little off its lower edge.)

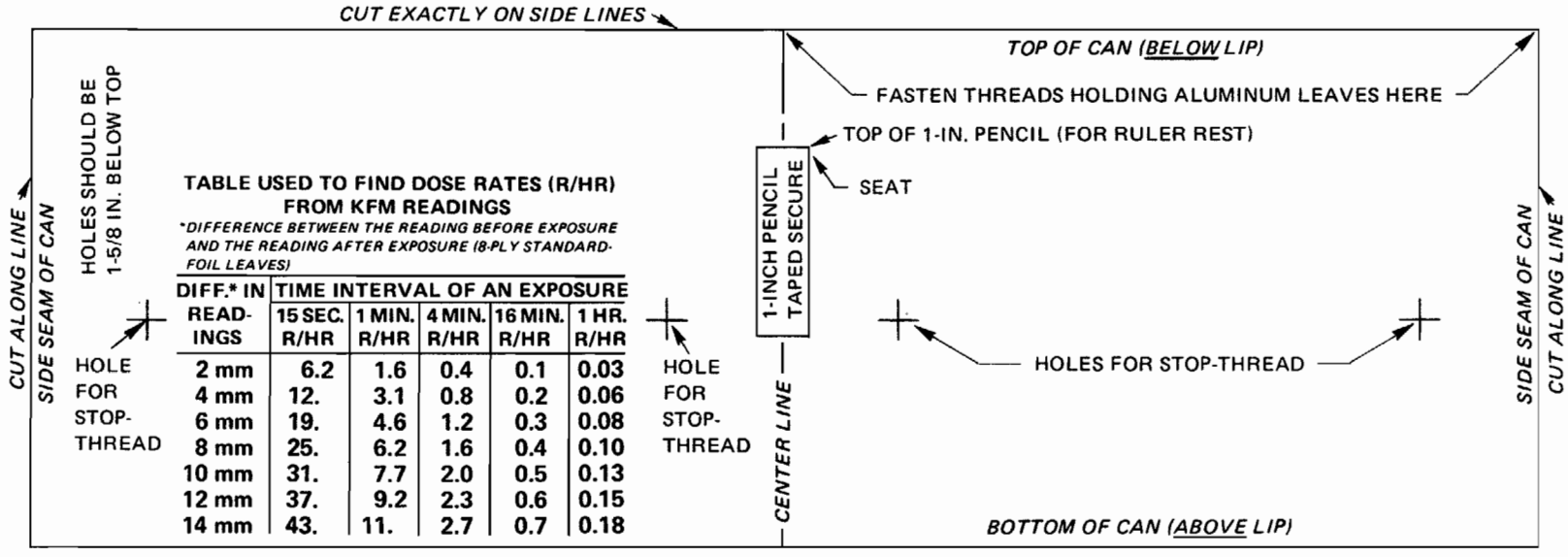
4. Sharpen a small nail, by filing or rubbing on concrete, for use as a punch to make the four holes needed to install the stop-threads in the ionization chamber (the can). (The stop-threads are insulators that stop the charged aluminum leaves from touching the can and being discharged.)

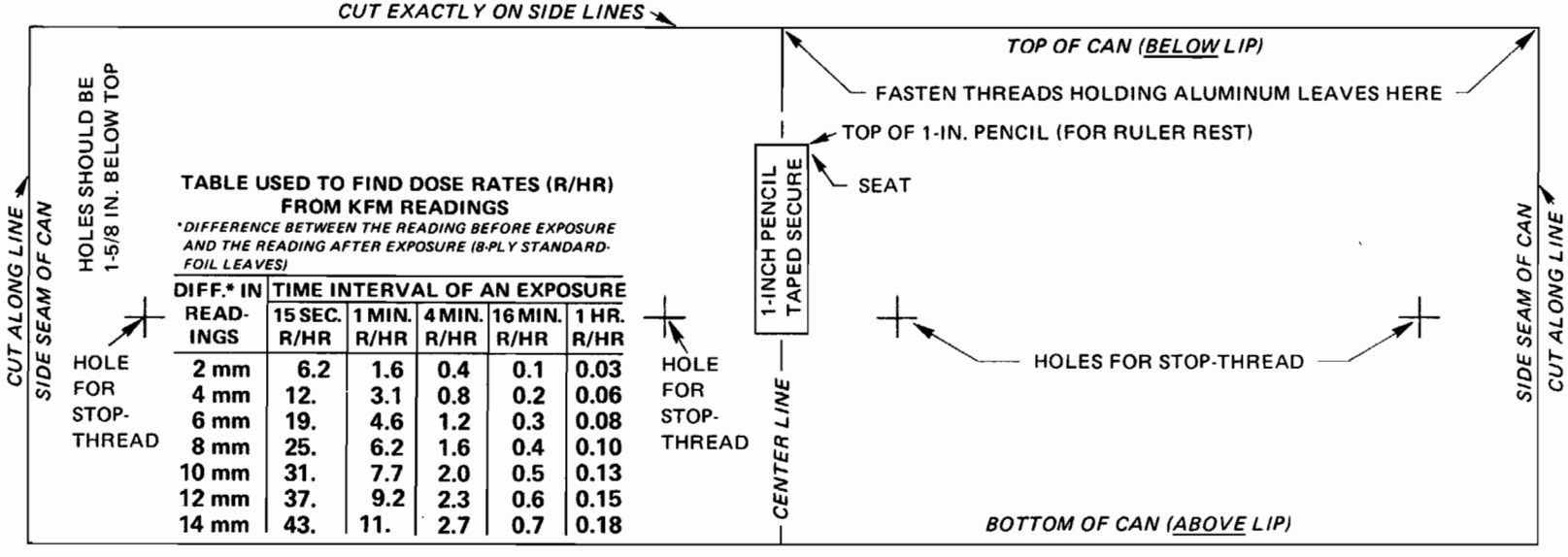
5. Have one person hold the can over a horizontal stick or a round wooden tool-handle, that ideally has a diameter about as large as the diameter of the can. Then a second person can use the sharpened nail and a hammer to punch four very small holes through the sides of the can at the points shown by the four crosses on the pattern. Make these holes just large enough to run a needle through them, and then move the needle in the holes so as to bend back the obstructing points of metal.

6. The stop-threads can be installed by using a needle to thread a single thread through all four holes. Use a **very clean** thread, preferably nylon, and do not touch the parts of this thread that will be inside the can and will serve as the insulating stop-threads. Soiled threads are poor insulators. (See illustrations.)



SINGLE THREAD THREADED THROUGH 4 HOLES TO MAKE 2 STOP-THREADS





PAPER PATTERN TO WRAP AROUND KFM CAN (GLUE OR TAPE SECURELY TO CAN)

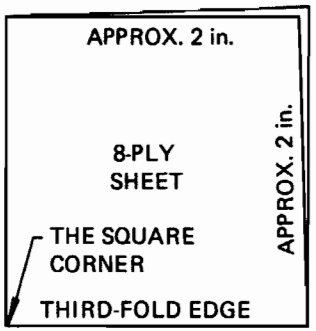
CUT OUT THESE PATTERNS, EACH OF WHICH IS THE EXACT SIZE FOR A KFM.

PATTERN PAGE (A) *CAUTION:* XEROX COPIES OF THESE PATTERNS WILL BE TOO LARGE.

Before threading the thread through the four holes, tie a **small** toggle (see the preceding sketch) to the long end of the thread. (This toggle can easily be made of a very small sliver of wood cut about 3/8 in. long.) After the thread has been pulled through the four holes, attach a second toggle to the thread, about 1/2 inch from the part of the thread that comes out of the fourth hole. Then the thread can be pulled tightly down the side of the can and the second small toggle can be taped securely in place to the side of the can. (If the thread is taped down without a toggle, it is likely to move under the tape.)

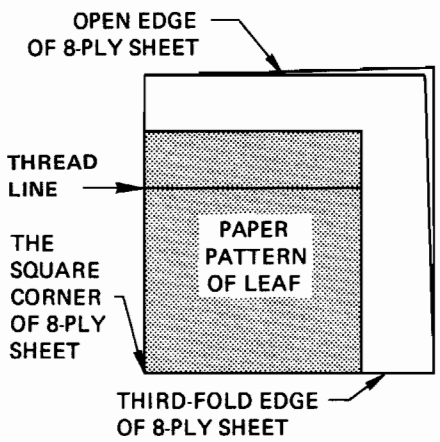
The first toggle and all of the four holes also should be covered with tape, to prevent air from leaking into the can after it has been covered and is being used as an ionization chamber.

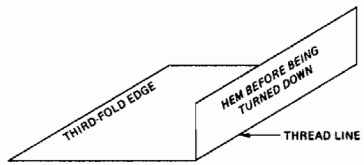
X. Make Two Separate 8-Ply Leaves of Standard [Not Heavy Duty*] Aluminum Foil



Proceed as follows to make each leaf:

1. Cut out a piece of standard aluminum foil approximately 4 inches by 8 inches.
2. Fold the aluminum foil to make a 2-ply (= 2 thicknesses) sheet approximately 4 inches by 4 inches.
3. Fold this 2-ply sheet to make a 4-ply sheet approximately 2 inches by 4 inches.
4. Fold this 4-ply sheet to make an 8-ply sheet (8 sheets thick) approximately 2 inches by 2 inches, being **sure** that the two halves of the second-fold edge are exactly together. This third folding makes an 8-ply aluminum foil sheet with **one corner exactly square.**
5. **Cut out** the FINISHED-LEAF PATTERN, found on the following Pattern Page B. Note that this pattern is **NOT** a square and that it is **smaller** than the 8-ply sheet. Flatten the 8 thicknesses of aluminum foil with the fingers until they appear to be a single thin, flat sheet.
6. Hold the FINISHED-LEAF PATTERN **on top of** the 8-ply aluminum foil sheet, with the pattern's THIRD-FOLD EDGE on top of the third-fold edge of the 8-ply aluminum sheet. Be sure that one lower **corner** of the FINISHED-LEAF PATTERN is on top of the **exactly square corner** of the 8-ply aluminum sheet.
7. While holding a straight edge along the THREAD LINE of the pattern, press with a sharp pencil so as to make a shallow groove for the THREAD LINE on the 8-ply aluminum sheet. Also using a sharp pencil, trace around the top and side of the pattern, so as to indent (groove) the 8-ply foil.
8. Remove the pattern, and cut out the 8-ply aluminum foil leaf.
9. While holding a straight edge along the indented THREAD LINE, lift up the OPEN EDGE of the 8-ply sheet (keeping all 8 plies together) until this edge is vertical, as illustrated. Remove the straight edge, and fold the 8-ply aluminum along the THREAD LINE so as to make a **flat-folded** hem.
10. Open the flat-folded hem of the finished leaf until the 8-ply leaf is almost flat again, as shown by the pattern, from which the FINISHED-LEAF PATTERN has already been cut.
11. Prepare to attach the aluminum-foil leaf to the thread that will suspend it inside the KFM.





8-PLY LEAF WITH ITS OPEN EDGE FOLDED TO VERTICAL POSITION

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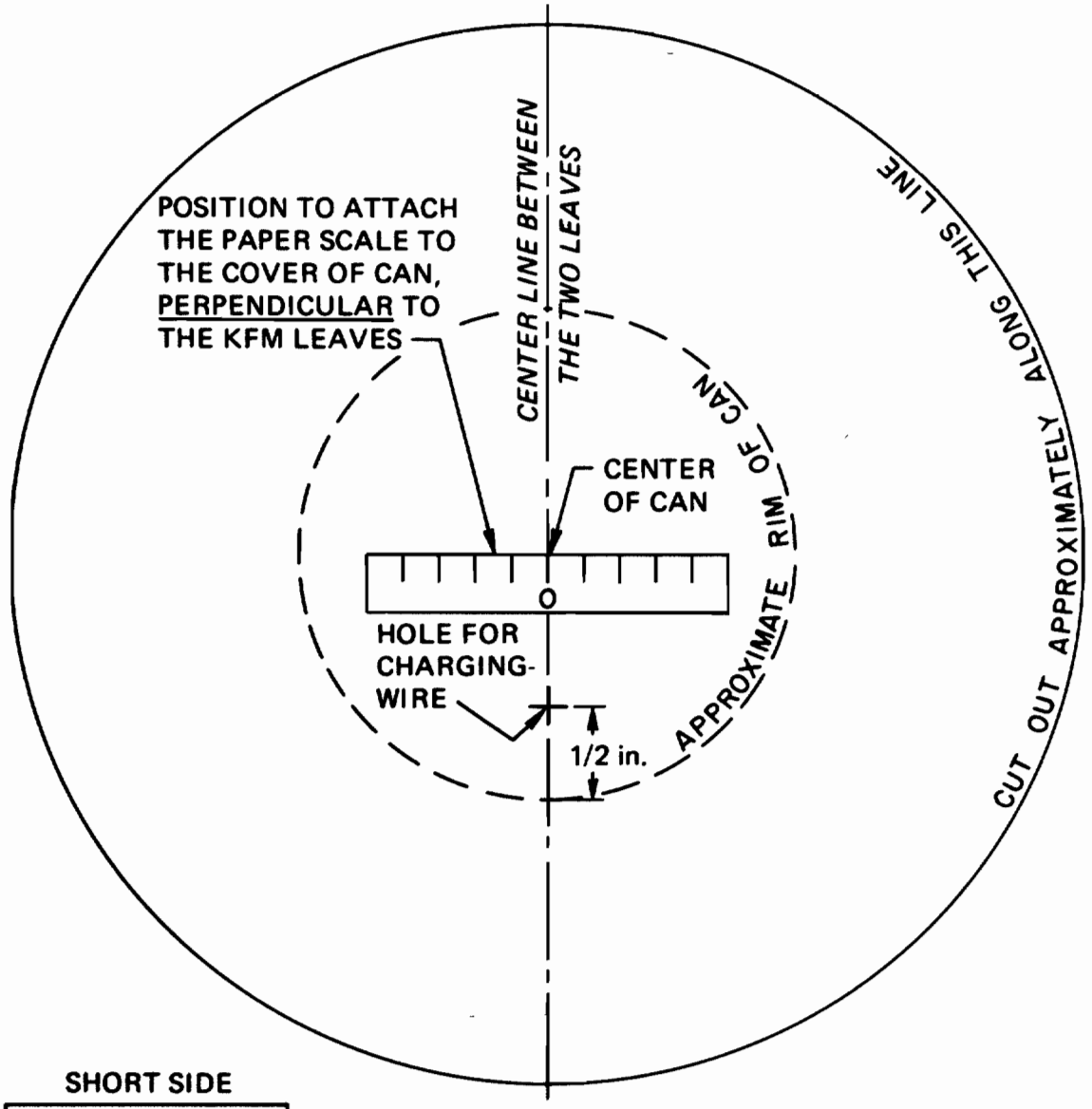
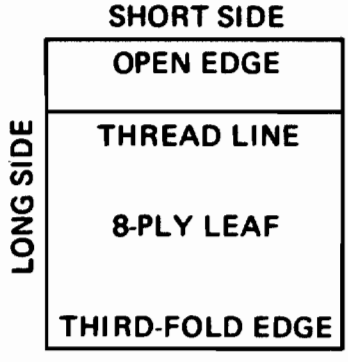
*If only heavy duty aluminum foil (sometimes called "extra heavy duty") is available, make 5-ply leaves of the same size, and use the table for the 8-ply KFM to determine radiation dose rates. To make a 5-ply leaf, start by cutting out a piece of foil approximately 4 inches by 4 inches. Fold it to make a 4-ply sheet approximately 2 inches by 2 inches, with one corner exactly square. Next from a single thickness of foil cut a square approximately 2 inches by 2 inches. Slip this square into a 4-ply sheet, thus making a 5-ply sheet. Then make the 5-ply leaf, using the FINISHED-LEAF PATTERN, etc. as described for making an 8-ply leaf.

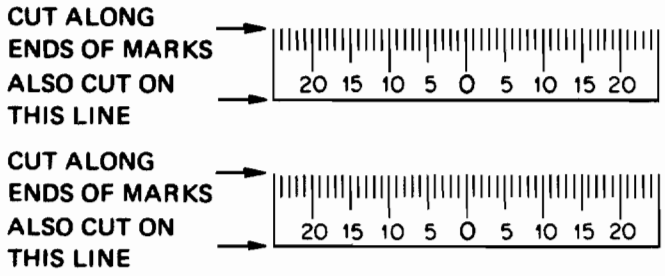
PATTERN FOR CLEAR-PLASTIC COVER FOR KFM CAN



SAVE THESE PATTERNS FOR PRINTING REPRODUCTIONS OF THE COMPLETE INSTRUCTIONS DURING A POSSIBLE CRISIS. FOR PRE-CRISIS PRACTICE CUT OUT PATTERNS FROM THE TWO EXTRA PATTERN-PAGES AT THE END OF THESE INSTRUCTIONS.



FINISHED-LEAF PATTERN
(CUT OUT EXACTLY ON SIDE LINES)



PAPER SCALE (TO BE CUT OUT)

PATTERN PAGE (B)

CAUTION: XEROX COPIES OF THE FINISHED-LEAF AND THE SCALE PATTERNS WILL BE SLIGHTLY TOO LARGE.

If no epoxy glue* is available to hold down the hem and prevent the thread from slipping in the hem, cut two pieces of tape (Band-Aid tape is best; next best is masking or freezer tape; next best, Scotch tape). After first peeling off the paper backing of Band-Aid tape, cut each piece of tape 1/8 inch by 1 inch long. Attach these two pieces of tape to the finished 8-ply aluminum leaf with the sticky sides up, except for their ends. As shown by the pattern on the following pattern page, secure 1/8 inch of one end of a tape strip near one corner of the 8-ply aluminum foil leaf by first turning under this 1/8-inch end; that is, with this end's sticky side down. Then turn under the other 1/8-inch-long end, and attach this end below the THREAD LINE. **Slant** each tape strip as illustrated on Pattern (C).

Be sure you have read through step 18 before you do anything else.

12. Cut an 8-1/2-inch piece of fine, unwaxed, **very clean** thread. (Fine nylon twisted thread, unwaxed extra-fine nylon dental floss, or fine silk thread are best in this order. However, any kind of fine, flexible **clean** thread will do quite well. Nylon monofilament "invisible" thread is an excellent insulator but is too difficult for most people to handle.)

    Cut out Pattern (C), the guide sheet used when attaching a leaf to its suspending thread. Then tape Pattern (C) to the top of a work table. Cover the two "TAPE HERE" rectangles on Pattern (C) with pieces of tape, each piece the size of the rectangle. Then cut two other pieces of tape each the same size and use them to **tape the thread ONTO the guide sheet**, on top of the "TAPE HERE" rectangles.

    Be very careful **not to touch** the two 1-inch parts of the thread next to the outline of the finished leaf, since oil and dirt even on clean fingers will reduce the electrical insulating value of the thread between the leaf and the top rim of the can.

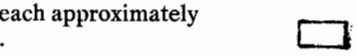
13. With the thread still taped to the paper pattern and while slightly lifting the thread with a knife tip held under the center of the thread, slip the finished leaf **under** the thread and into position exactly on the top of the leaf outlined on the pattern page. Hold the leaf in this position with two fingers.

14. While keeping the thread straight between its two taped-down ends, lower the thread so that it sticks to the two plastic strips. Then press the thread against the plastic strips.

15. With the point of the knife, hold down the center of the thread against the center of the THREAD LINE of the leaf. Then, with two fingers, carefully fold over the hem and press it almost flat. Be sure that the thread comes out of the corners of the hem. Remove the knife, and press the hem down completely flat against the rest of the leaf.

16. Make **small** marks on the thread at the two points shown on the pattern page. Use a ballpoint pen if available.

17. Loosen the second two small pieces of tape from the pattern paper, but leave these tapes stuck to the thread.

18. Cut 5 pieces of Band-Aid tape, each approximately 1/8 inch by 1/4 inch, this small. 

    Use 2 of these pieces of tape to secure the centers of the side edges of the leaf. Place the 5 pieces as illustrated in the SIDE VIEW sketch below.

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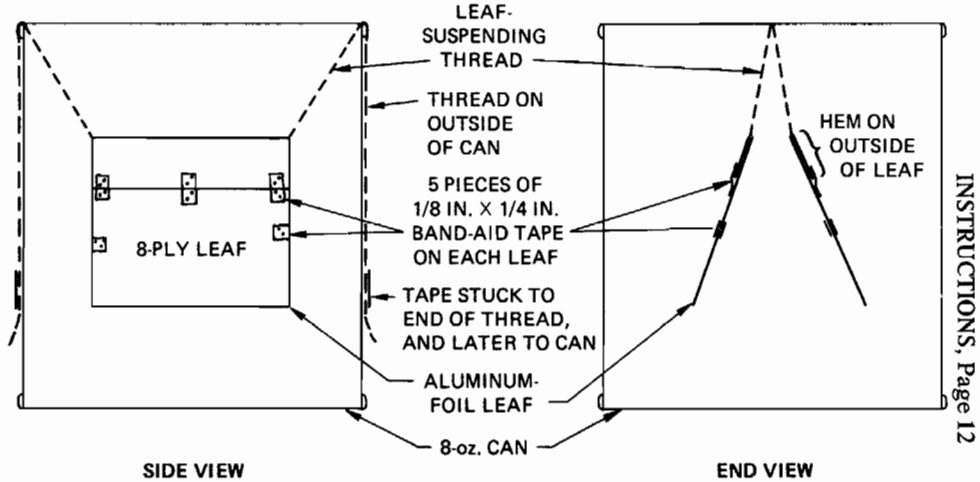
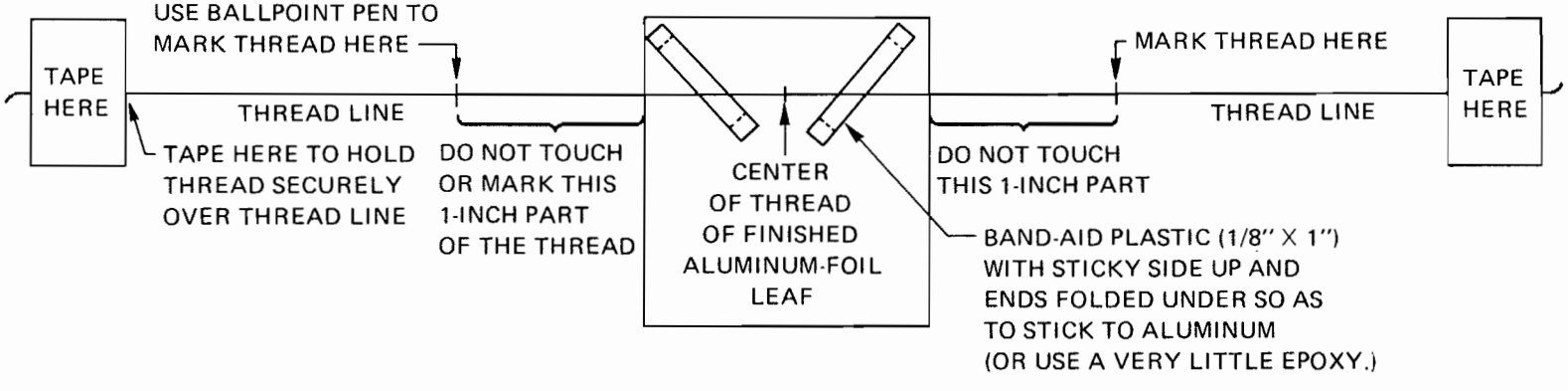


SHOWING THE TWO LEAVES CHARGED (WHEN NOT CHARGED, THE LEAVES HANG PERPENDICULAR AND TOUCHING.)

*If using epoxy or other glue, use only a **very** little to hold down the hem, to attach the thread securely to the leaf and to glue together any open edges of the plied foil. Most convenient is "one hour" epoxy, applied with a toothpick. Model airplane cement requires hours to harden when applied between sheets of aluminum foil. To make sure no glue stiffens the free thread beyond the upper corners of the finished leaf, put no glue within 1/4 inch of a point where thread will go out from the folded hem of the leaf.

The instructions in step 11 are for persons lacking "one hour" epoxy or the time required to dry other types of glue. Persons using glue instead of tape to attach the leaf to its thread should make appropriate use of the pattern on the following page and of some of the procedures detailed in steps 12 through 18.

COVER THE TWO "TAPE HERE" RECTANGLES WITH SAME-SIZED PIECES OF TAPE, IN ORDER TO KEEP FROM TEARING THIS PAPER WHEN REMOVING TWO ADDITIONAL PIECES OF TAPE. THEN, BY PUTTING TWO OTHER PIECES OF TAPE THIS SAME SIZE ON TOP OF THE FIRST TWO PIECES, TAPE THE THREAD ONTO THIS GUIDE SHEET, AND LATER ATTACH A LEAF TO THE TAPED-DOWN THREAD.



PATTERN (C)
(Cut out this guide along its border lines and tape to the top of a work table.)

WARNING: The parts of the thread that will be inside the can and on which the leaf will be suspended must serve to insulate the high-voltage electrical charges to be placed on the leaf. Therefore, the suspended parts of the thread must be kept very clean.

XI. Install the Aluminum-Foil Leaves

1. Use the two small pieces of tape stuck to the ends of a leaf-suspending thread to attach the thread to the outside of the can. Attach the tapes on opposite sides of the can, so as to suspend the leaf inside the can. See END VIEW sketch. Each of the two **marks** on the attached thread MUST **rest exactly on the top of the rim of the can**, preferably in two **very small** notches filed in the top of the rim of the can. Each of these two marks on a thread should be positioned exactly above one of the two points shown on the pattern wrapped around the can. Be sure that the hem-side of each of the two leaves faces outward. See END VIEW sketch.

2. Next, the suspending thread of the first leaf should be taped to the top of the rim. Use a piece of Band-Aid only about 1/8 in. x 1/4 in., sticking it to the rim of the can so as barely to cover the thread on the side where the second leaf will be suspended. Make sure no parts of the tapes are inside the can.

3. Position and secure the second leaf, being sure that:

   a. The smooth sides of the two leaves are smooth (not bent) and face each other and are flush (= "right together") when not charged. See END VIEW sketch and study the first photo illustration, "An Uncharged KFM".

   b. The upper edges of the two leaves are suspended side by side and at the same distance below the top of the can.

   c. The leaf-suspending threads are taped with Band-Aid to the top of the rim of the can (so that putting the cover on will not move the threads).

   d. No parts of the leaf-suspending threads inside the can are taped down to the can or otherwise restricted.

   e. The leaf-suspending parts of the threads inside the can do not cross over, entangle or restrict each other.

   f. The threads come together on the top of the rim of the can, and that the leaves are flat and hang together as shown in the first photo illustration, "An Uncharged KFM."

   g. If the leaves do not look like these photographed leaves, make new, better leaves and install them.

4. Cover with tape the parts of the threads that extend down the **outside** of the can, and also cover with more tape the small pieces of tape near the ends of the threads on the outside of the can.

5. To make the SEAT, cut a piece of a wooden pencil, or a stick, about one inch long and tape it securely to the side of the can along the center line marked SEAT on the pattern. Be sure the upper end of this piece of pencil is at the same position as the top of the location for the SEAT outlined on the pattern. The top of the SEAT is 3/4 inch below the top of the can. Be sure not to cover or make illegible any part of the table printed on the paper pattern.

6. Cut out one of the "Reminders for Operators" and glue and/or tape it to the unused side of the KFM. Then it is best to cover all the sides of the finished KFM with clear plastic tape or varnish. This will keep sticky-tape on the end of an adjustment thread or moisture from damaging the "Reminders" or the table.

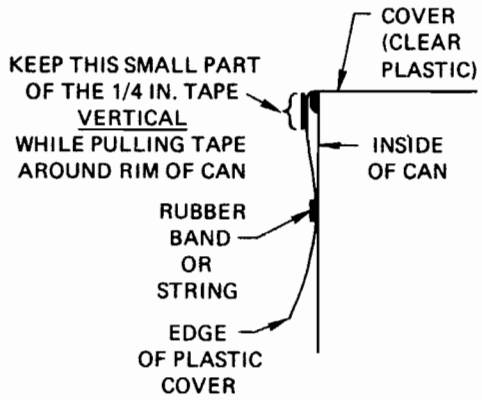
XII. Make the Plastic Cover

1. Cut out the paper pattern for the cover from the Pattern Page (B).

2. From a piece of clear, strong plastic, cut a circle approximately the same size as the paper pattern. (Storm-window vinyl film, 4 mils thick, is best.)

3. Stretch the center of this circular piece of clear plastic over the open end of the can, and pull it down close to the sides of the can, making small tucks in the "skirt," so that there are no wrinkles in the top cover. Hold the lower part of the "skirt" in place with a strong rubber band or piece of string. (If another can having the same diameter as the KFM can is available, use it to make the cover -- to avoid the possibility of disturbing the leaf-suspending threads.)

4. Make the cover so it fits snugly, but can be taken off and replaced readily.



Just below the top of the rim of the can, bind the covering plastic in place with a 1/4-inch-wide piece of strong tape. (Cloth duct tape is best. If only freezer or masking tape is available, use two thicknesses.)

Keep vertical the small part of the tape that presses against the rim of the can while pulling the length of the tape horizontally around the can so as to bind the top of the plastic cover snugly to the rim. If this small part of the tape is kept vertical, the lower edge of the tape will not squeeze the plastic below the rim of the can to such a small circumference as to prevent the cover from being removed quite easily.

REMINDERS FOR OPERATORS

THE DRYING AGENT INSIDE A KFM IS O.K. IF, WHEN THE CHARGED KFM IS NOT EXPOSED TO RADIATION, ITS READINGS DECREASE BY 1 MM OR LESS IN 3 HOURS.

READING: WITH THE READING EYE 12 INCHES VERTICALLY ABOVE THE SEAT, NOTE ON THE MM SCALE THE SEPARATION OF THE LOWER EDGES OF THE LEAVES. IF THE RIGHT LEAF IS AT 10 MM AND THE LEFT LEAF IS AT 7 MM, THE KFM READS 17 MM. NEVER TAKE A READING WHILE A LEAF IS TOUCHING A STOP-THREAD. NEVER USE A KFM READING THAT IS LESS THAN 5MM.

FINDING A DOSE RATE: IF BEFORE EXPOSURE A KFM READS 17 MM AND IF AFTER A 1-MINUTE EXPOSURE IT READS 5 MM, THE DIFFERENCE IN READINGS IS 12 MM, THE ATTACHED TABLE SHOWS THE DOSE RATE WAS 9.6 R/HR DURING THE EXPOSURE.

FINDING A DOSE: IF A PERSON WORKS OUTSIDE FOR 3 HOURS WHERE THE DOSE RATE IS 2 R/HR, WHAT IS HIS RADIATION DOSE? ANSWER: 3 HR x 2 R/HR = 6 R.

FINDING HOW LONG IT TAKES TO GET A CERTAIN R DOSE: IF THE DOSE RATE IS 1.6 R/HR OUTSIDE AND A PERSON IS WILLING TO TAKE A 6 R DOSE, HOW LONG CAN HE REMAIN OUTSIDE? ANSWER:

6 R ÷ 1.6 R/HR = 3.75 HR =

3 HOURS AND 45 MINUTES.

FALLOUT RADIATION GUIDES FOR A HEALTHY PERSON NOT PREVIOUSLY EXPOSED TO A TOTAL RADIATION DOSE OF MORE THAN 100 R DURING A 2-WEEK PERIOD:

6 R PER DAY CAN BE TOLERATED FOR UP TO TWO MONTHS WITHOUT LOSING THE ABILITY TO WORK.

100 R IN A WEEK OR LESS IS NOT LIKELY TO SERIOUSLY SICKEN.

350 R IN A FEW DAYS IS LIKELY TO PROVE FATAL UNDER POST-ATTACK CONDITIONS.

600 R IN A WEEK OR LESS IS ALMOST CERTAIN TO CAUSE DEATH WITHIN A FEW WEEKS.

REMINDERS FOR OPERATORS

THE DRYING AGENT INSIDE A KFM IS O.K. IF, WHEN THE CHARGED KFM IS NOT EXPOSED TO RADIATION, ITS READINGS DECREASE BY 1 MM OR LESS IN 3 HOURS.

READING: WITH THE READING EYE 12 INCHES VERTICALLY ABOVE THE SEAT, NOTE ON THE MM SCALE THE SEPARATION OF THE LOWER EDGES OF THE LEAVES. IF THE RIGHT LEAF IS AT 10 MM AND THE LEFT LEAF IS AT 7 MM, THE KFM READS 17 MM. NEVER TAKE A READING WHILE A LEAF IS TOUCHING A STOP-THREAD. NEVER USE A KFM READING THAT IS LESS THAN 5MM.

FINDING A DOSE RATE: IF BEFORE EXPOSURE A KFM READS 17 MM AND IF AFTER A 1-MINUTE EXPOSURE IT READS 5 MM, THE DIFFERENCE IN READINGS IS 12 MM, THE ATTACHED TABLE SHOWS THE DOSE RATE WAS 9.6 R/HR DURING THE EXPOSURE.

FINDING A DOSE: IF A PERSON WORKS OUTSIDE FOR 3 HOURS WHERE THE DOSE RATE IS 2 R/HR, WHAT IS HIS RADIATION DOSE? ANSWER: 3 HR x 2 R/HR = 6 R.

FINDING HOW LONG IT TAKES TO GET A CERTAIN R DOSE: IF THE DOSE RATE IS 1.6 R/HR OUTSIDE AND A PERSON IS WILLING TO TAKE A 6 R DOSE, HOW LONG CAN HE REMAIN OUTSIDE? ANSWER:

6 R ÷ 1.6 R/HR = 3.75 HR =

3 HOURS AND 45 MINUTES.

FALLOUT RADIATION GUIDES FOR A HEALTHY PERSON NOT PREVIOUSLY EXPOSED TO A TOTAL RADIATION DOSE OF MORE THAN 100 R DURING A 2-WEEK PERIOD:

6 R PER DAY CAN BE TOLERATED FOR UP TO TWO MONTHS WITHOUT LOSING THE ABILITY TO WORK.

100 R IN A WEEK OR LESS IS NOT LIKELY TO SERIOUSLY SICKEN.

350 R IN A FEW DAYS IS LIKELY TO PROVE FATAL UNDER POST-ATTACK CONDITIONS.

600 R IN A WEEK OR LESS IS ALMOST CERTAIN TO CAUSE DEATH WITHIN A FEW WEEKS.

5. With scissors, cut off the "skirt" of the plastic cover until it extends only about one inch below the top of the rim of the can.

6. Make a notch in the "skirt," about one inch wide, where it fits over the pencil SEAT attached to the can. The "skirt" in this notched area should be only about 5/8 of an inch long, measured down from the top of the rim of the can.

7. Remove the plastic cover, and then tape the lower edges of the "skirt," inside and out, using short lengths of 1/4-inch-wide tape. Before securing each short piece of tape, slightly open the tucks that are being taped shut on their edges, so that the "skirt" flares slightly outward and the cover can be readily removed.

8. Put the plastic cover on the KFM can. From the Pattern Page (B) cut out the SCALE. Then tape the SCALE to the top of the plastic cover, in the position shown on the pattern for the cover, and also by the drawings. Preferably use transparent tape.

   Be careful not to cover with tape any of the division lines on the SCALE between 20 on the right and 20 on the left of 0.

9. Make the charging-wire by following the pattern given below which is **exactly the right size.**

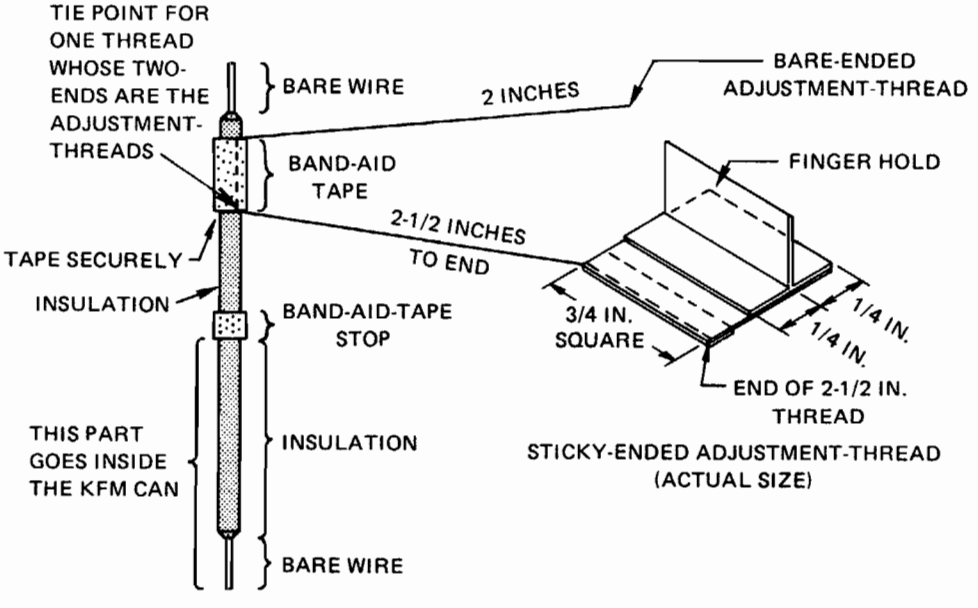
   Doorbell wire with an outside diameter of about 1/16 inch is best, but any lightweight insulated wire, such as part of a lightweight two-wire extension cord split in half, will serve. The illustrated wire is much thicker than bell wire. To stop tape from possibly slipping up or down the wire, use a very little glue.

   If a very thin plastic has been used for the cover, a sticky piece of tape may need to be attached to the end of the bare-ended adjustment thread, so both threads can be used to hold the charging wire in a desired position.

   The best tape to attach to an end of one of the adjustment-threads is cloth duct tape. A square piece 3/4 inch by 3/4 inch is the sticky base. To keep this tape sticky (free of paper fibers), the paper on the can should be covered with transparent tape or varnish. A piece about 1/8 inch by 3/4 inch serves to stick under one end of the sticky base, to hold the adjustment-thread. A 3/4 inch by 1-1/4 inch rectangular piece of tape is used to make the finger hold -- important for making adjustments inside a dry-bucket.

   With a needle or pin, make a hole in the plastic cover 1/2 inch from the rim of the can and directly above the upper end of the CENTER LINE between the two leaves. The CENTER LINE is marked on the pattern wrapped around the can. Carefully push the CHARGING-WIRE through this hole (thus stretching the hole) until all of the CHARGING-WIRE below its Band-Aid-tape stop is inside the can.

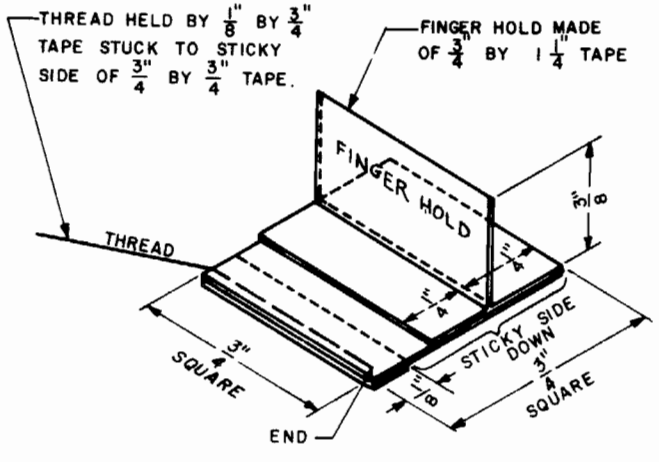
EXACT SIZE



CHARGING-WIRE

(= LIGHT INSULATED WIRE)
(BELL-WIRE IS BEST)

STICKY—ENDED ADJUSTMENT—THREAD (OVERSIZED DRAWING)

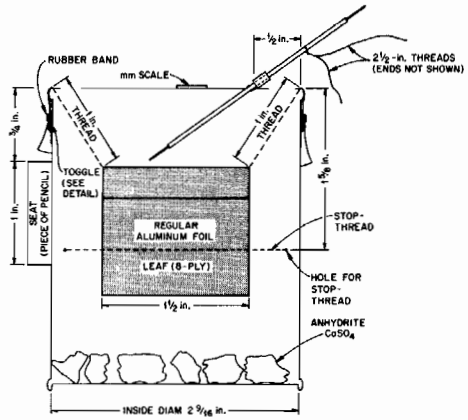


XIII. Two Ways to Charge a KFM

When preparing to charge a KFM, be sure its anhydrite is fresh. (Under humid conditions, sometimes in only 2 days enough water vapor will go through the plastic cover to make the drying agent ineffective.) Be sure no piece of anhydrite is on top of another piece. Re-read VIII 7 and VIII 8.

1. Charging a KFM with Hard Plastic Rubbed on **Dry** Paper.

   a. Adjust the charging-wire so that its lower end is about 1/16 inch above the upper edges of the aluminum-foil leaves. Use the sticky-tape at the end of one adjustment-thread to hold the charging-wire in this position. Stick this tape approximately in line with the threads suspending the leaves, either on the side of the can or on top of the plastic cover. (If the charging-wire is held loosely by the cover, it may be necessary to put a piece of sticky-tape on the end of each adjustment-thread in order to adjust the charging-wire securely. If a charging-wire is not secure, its lower end may be forced up by the like charge on the leaves before the leaves can be fully charged.)

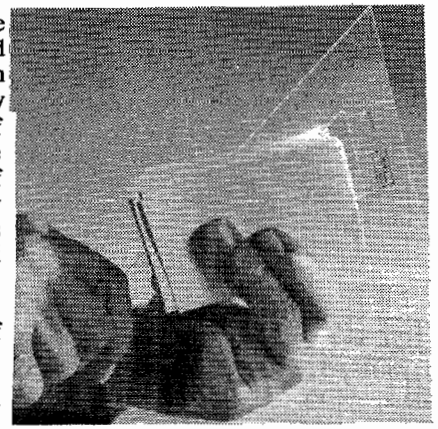


   b. Select a piece of Plexiglas, a draftsman's plastic triangle, a smooth plastic ruler, or other piece of hard, smooth plastic. (Unfortunately, not all types of hard plastic can be used to generate a sufficient electrostatic charge.) Be sure the plastic is dry.

      For charging a KFM inside a dry-bucket, cut a rectangular piece of hard plastic about 1-1/2 by 5 inches. Sharp corners and edges can be smoothed by rubbing on concrete. To avoid contaminating the charging end with sweaty, oily fingers, it is best to mark the other end with a piece of tape.

   c. Fold **DRY** paper (typing paper, writing paper, or other smooth, clean paper) to make an approximate square about 4 inches on a side and about 20 sheets thick. (This many sheets of paper lessens leakage to the fingers of the electrostatic charges to be generated on the hard plastic and on the rubbed paper.)

   d. Fold the square of paper in the middle, and move the hard plastic rapidly back and forth so that it is rubbed **vigorously** on the paper in the middle of this folded square -- while the outside of this folded square of paper is squeezed firmly between thumb and the ends of **two** fingers. To avoid discharging the charge on the plastic to the fingers, keep them away from the edges of the paper. See photo.



   e. Move the electrostatically charged part of the rubbed plastic rather slowly past the upper end of the charging-wire, while looking straight down on the KFM. Keep the hard plastic approximately perpendicular to the charging-wire and about 1/4 to 1/2 inch away from its upper end. The charge jumps the spark gaps and charges the leaves of the KFM.

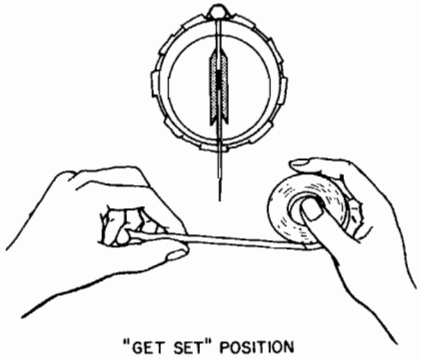
   f. Pull down on an insulating adjustment-thread to raise the lower end of the charging-wire. (If the charging-wire has been held in its charging position by its sticky-ended adjustment-thread being stuck to the top of the clear plastic cover, to avoid possibly damaging the threads: (1) pull down a little on the bare-ended adjustment-thread; and (2) detach, pull down on, and secure the sticky-ended adjustment-thread to the side of the can, so as to raise and keep the lower end of the charging-wire close to the underside of the clear plastic cover.) **Do not touch the charging-wire.**

   g. Put the charging paper and the hard plastic in a container where they will be kept dry -- as in a Mason jar with some drying agent.

2. Charging a KFM from a Quickly Unwound Roll of Tape. (Quick unwinding produces a harmless charge of several thousand volts on the tape.)

   a. Adjust the charging-wire so that its lower end is about 1/16 inch above the upper edges of the aluminum-foil leaves. Use the sticky-tape at the end of one adjustment-thread to hold the charging-wire in this position. Stick this tape approximately in line with the leaves, either on the side of the can or on the plastic cover. (If the plastic cover is weak, it may be necessary to put a piece of sticky-tape on the end of each adjustment-thread, in order to hold the charging-wire securely. If a charging-wire is not secure, its lower end may be forced up by the like charge on the leaves before the leaves can be fully charged.)

b. The sketch shows the "GET SET" position, preparatory to unrolling the Scotch Magic Transparent Tape, P.V.C. electrical tape, or other tape. Be sure to first remove the roll from its dispenser. Some of the other kinds of tape will not produce a high enough voltage.



"GET SET" POSITION

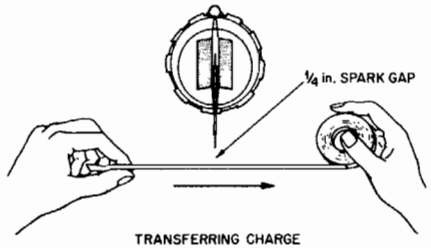
c. **QUICKLY** unroll 10 to 12 inches of tape by pulling its end with the left hand, while the right hand allows the roll to unwind while remaining in about the same "GET SET" position only an inch or two away from the KFM.

d. While holding the unwound tape tight, about perpendicular to the charging-wire, and about 1/4 inch away from the end of the charging-wire, **promptly** move both hands and the tape to the right **rather slowly** -- taking about 2 seconds to move about 8 inches. The electrostatic charge on the unwound tape "jumps" the spark gaps from the tape to the upper end of the charging-wire and from the lower end of the charging-wire to the aluminum leaves, and charges the aluminum leaves.

Be sure neither leaf is touching a stop-thread.

Try to charge the leaves enough to spread them far enough apart to give a reading of at least 15 mm.

e. Pull down on an insulating adjustment-thread to raise the lower end of the charging-wire. If the charging-wire has been held in charging position by its sticky-ended adjustment-thread being stuck to the top of the clear plastic cover, it is best first to pull down a little on the bare-ended adjustment-thread, and then to move, pull down on, and secure the sticky-ended adjustment-thread to the side of the can so that the lower part of the charging-wire is close to the underside of the clear plastic cover.



TRANSFERRING CHARGE

Do not touch the charging-wire.

f. Rewind the tape **tight** on its roll, for future use when other tape may not be available.

Trouble Shooting

If charging does not separate the two leaves sufficiently, take these corrective actions:

1. Be sure the pieces of anhydrite in the bottom of the ionization chamber (the can) are in a single layer, with no piece on top of another and the top of no piece more than ½ inch above the bottom of the can.

2. Check to be sure that the threads suspending the leaves are not crossed; then try to charge the KFM again.

3. If the KFM still cannot be charged, replace the used anhydrite with fresh anhydrite.

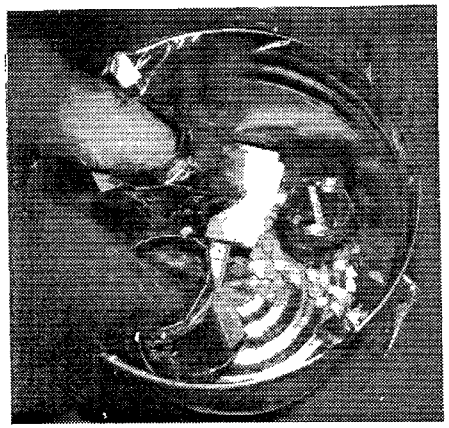
4. If you cannot charge a KFM when the air is very humid, charge it inside its dry-bucket.

5. If you cannot charge a KFM while in an area of heavy fallout, take it to the place affording the best protection against radiation, and try to charge it there. (A dose rate of several hundred R/hr will neutralize the charges on both the charging device and the instrument so rapidly that a KFM cannot be charged.)

If a KFM or other radiation measuring instrument gives unexpectedly high readings inside a good shelter, wipe all dust off the outside of the instrument and repeat the radiation-measurements. Especially when exposing a fallout meter outdoors where there is fresh fallout, keep the instrument in a lidded pot, plastic bag, or other covering to avoid the possibility of having it contaminated with fallout particles and afterwards getting erroneously high radiation measurements.

XIV. **Make and Use a Dry-Bucket**

By charging a KFM while it is inside a dry-bucket with a transparent plastic cover (see illustration), this fallout meter can be charged and used even if the relative humidity is 100% outside the dry-bucket. The air inside the dry-bucket is kept very dry by a drying agent placed on its bottom. About a cupful of anhydrite serves very well. The pieces of this dehydrated gypsum need not be as uniform in size as is best for use inside a KFM, but do not use powdered anhydrite.

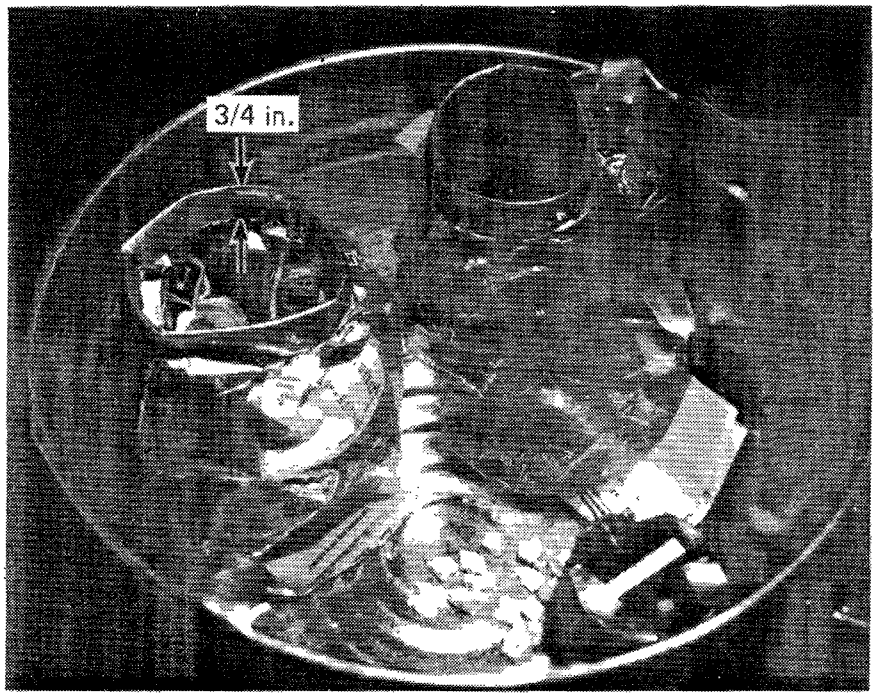


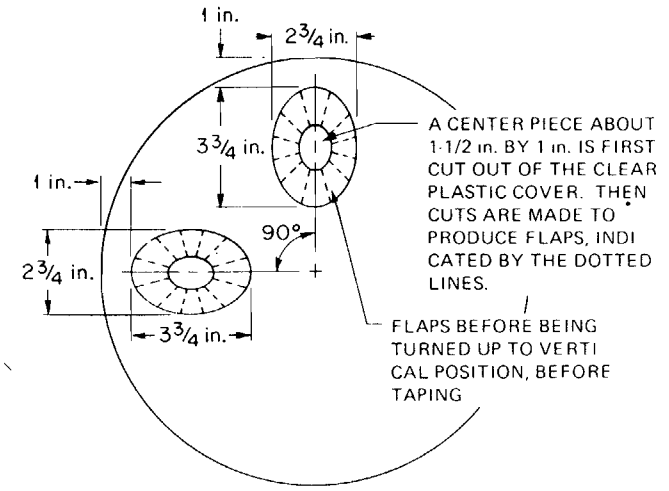
A dry-bucket can be readily made in about an hour by proceeding as follows:

1. Remove the handle of a large bucket, pot, or can preferably with a top diameter of at least 11 inches. A 4-gallon bucket having a top diameter of about 14 inches and a depth of about 9 inches is ideal. A plastic tub approximately this size is satisfactory. If the handle-supports interfere with stretching a piece of clear plastic film across the top of the bucket, remove them, being sure no sharp points remain.

2. Cut out a circular piece of clear plastic with a diameter about 5 inches larger than the diameter of the top of the bucket. Clear vinyl 4 mils thick, used for storm windows, etc., is best. Stretch the plastic smooth across the top of the bucket, and tie it in place, preferably with strong rubber bands looped together to form a circle.

3. Make a plastic top that fits snugly but is easily removable, by taping over and around the plastic just below the top of the bucket. **One**-inch-wide cloth duct tape, or **one**-inch-wide glass-reinforced strapping tape, serves well. When taping, do not permit the lower edge of the tape to be pulled inward below the rim of the bucket.





4. Cut two small holes (about 1 inch by 2 inches) in the plastic cover, as illustrated. Then make the radial cuts (shown by dotted lines) outward from the small holes, out to the solid-line outlines of the 3 inch by 4 inch hand-holes, so as to form small flaps.

5. Fold the small flaps upward, so they are vertical. Then tape them on their outer sides, so they form a vertical "wall" about 3/4 inch high around each hand-hole.

6. Reduce the length of two ordinary plastic bread bags (or similar plastic bags) to a length that is 5 inches greater than the height of the bucket. (Do not use rubber gloves in place of bags; gloves so used result in much more humid outside air being unintentionally pumped into a dry-bucket when it is being used while charging a KFM inside it.)

7. Insert a plastic bag into each hand-hole, and fold the edge of the plastic bag about 1/2 inch over the taped vertical "wall" around each hand-hole.

8. Strengthen the upper parts of the plastic bags by folding 2-inch pieces of tape over the top of the "wall" around each hand-hole.

9. Make about a quart of anhydrite by heating small pieces of wall-board gypsum, and keep this anhydrite dry in a Mason jar or other airtight container with a rubber or plastic sealer.

10. Make a circular aluminum-foil cover to place over the plastic cover when the dry-bucket is not being used for minutes to hours. Make this cover with a diameter about 4 inches greater than the diameter of the top of the bucket, and make it fit more snugly with an encircling loop of rubber bands, or with string. Although not essential, an aluminum-foil cover reduces the amount of water vapor that can reach and pass through the plastic cover, thus extending the life of the drying agent.

11. Charge a KFM inside a dry-bucket by:

    a. Taking off wrist watch and sharp-pointed rings that might tear the plastic bags.

    b. Placing inside the dry-bucket:

        (1) About a cup of anhydrite or silica gel;
        (2) the KFM, with its charging-wire adjusted in its charging position; and
        (3) dry, folded paper and the electrostatic charging device, best a 5-inch-long piece of Plexiglas with smoothed edges, to be rubbed between dry paper folded about 4 inches square and about 20 sheets thick. (Unrolling a roll of tape inside a dry-bucket is an impractical charging method.)

    c. Replacing the plastic cover, that is best held in place with a loop of rubber bands.

    d. Charging the KFM with your hands inside the plastic bags, operating the charging device. Have another person illuminate the KFM with a flashlight. When adjusting the charging-wire, move your hands very slowly. See the dry-bucket photos.

12. Expose the KFM to fallout radiation **either** by:

    a. Leaving the KFM inside the dry-bucket while exposing it to fallout radiation for one of the listed time intervals, and reading the KFM before and after the exposure while it remains inside the dry-bucket. (The reading eye should be a measured 12 inches above the SEAT of the KFM, and a flashlight or other light should be used.)

    b. Taking the charged KFM out of the dry-bucket to read it, expose it, and read it after the exposure. (If this is done repeatedly, especially in a humid shelter, the drying agent will not be effective for many KFM chargings, and will have to be replaced.)

XV. How to Use a KFM after a Nuclear Attack

A. Background Information

If during a rapidly worsening crisis threatening nuclear war you are in the place where you plan to take shelter, postpone studying the instructions following this sentence until after you have:

(1) built or improved a high-protection-factor shelter (if possible, a shelter covered with 2 or 3 ft of earth and separate from flammable buildings), and

(2) made a KAP (homemade shelter-ventilating pump) if you have the instructions and materials, and

(3) stored at least 15 gallons of water for each shelter occupant if you can obtain containers.

Having a KFM or any other dependable fallout meter and knowing how to operate it will enable you to minimize radiation injuries and possible fatalities, especially by skillfully using a high-protection-factor fallout shelter to control and limit exposures to radiation. By studying this section you first will learn how to measure radiation **dose rates** (roentgens per hour = R/hr), how to calculate **doses** [**R**] received in different time intervals, and how to determine **time intervals** (hours and/or minutes) in which specified doses would be received. Then this section lists the sizes of doses (number of R) that the average person can tolerate without being sickened, that he is likely to survive, and that he is likely to be killed by.

Most fortunately for the future of all living things, the decay of radioactivity causes the sandlike fallout particles to become less and less dangerous with the passage of time. Each fallout particle acts much like a tiny X ray machine would if it were made so that its rays, shooting out from it like invisible light, became weaker and weaker with time.

Contrary to exaggerated accounts of fallout dangers, the radiation **dose rate** from fallout particles when they reach the ground in the areas of the heaviest fallout **will decrease quite rapidly**. For example, consider the decay of fallout from a relatively nearby, large surface burst, at a place where the fallout particles are deposited on the ground one hour after the explosion. At this time one hour after the explosion, assume that the radiation dose rate (the best measure of radiation danger at a particular time) measures 2,000 roentgens per hour (2,000 R/hr) outdoors. Seven hours later the dose rate is reduced to 200 R/hr by normal radioactive decay. Two days after the explosion, the dose rate outdoors is reduced by radioactive decay to 20 R/hr. After two weeks, the dose rate is less than 2 R/hr. When the dose rate is 2 R/hr, people can go out of a good shelter and work outdoors for 3 hours a day, receiving a daily dose of 6 roentgens, without being sickened.

In places where fallout arrives several hours after the explosion, the radioactivity of the fallout will have gone through its time period of most rapid decay while the fallout particles were still airborne. If you are in a location so distant from the explosion that fallout arrives 8 hours after the explosion, two days must pass before the initial dose rate measured at your location will decay to 1/10 its initial intensity.

B. Finding the **Dose Rate**

1. Reread Section IV, "What a KFM Is and How it Works." Also reread Section XIII, "Two Ways to Charge a KFM," and actually do each step immediately after reading it.

2. Charge the KFM, raise the lower end of its charging-wire and read the apparent separation of the **lower** edges of its leaves while the KFM rests on an approximately horizontal surface. Never take a reading while a leaf is touching a stop-thread.

3. To prevent possible contamination of a KFM (or of any other fallout meter) with fallout particles, keep it inside a plastic bag or other covering when there is risk of fallout particles being deposited or blown onto it. An instrument contaminated with fallout particles can give too high readings, especially of the low dose-rate measurements made inside a good shelter.

4. Expose the KFM to fallout radiation for one of the time intervals shown in the vertical columns of the table attached to the KFM. (Study the following table.) If the dose rate is not known even approximately, first expose the fully charged KFM for one minute. For dependable measurements outdoors, expose the charged KFM about 3 **feet above the ground**. The longer outdoor exposures usually are best made by attaching the KFM with 2 strong rubber bands to a stick or pole, being careful never to tilt the KFM too much.

5. Read the KFM after the exposure, while the KFM rests on an approximately horizontal surface.

6. Find the time interval that gives a dependable reading -- by exposing the fully charged KFM for one or more of the listed time intervals until the **reading after the exposure is;**

   (a) Not less than **5 mm.**

   (b) At least **2 mm** less than the reading before the exposure.

7. Calculate by simple subtraction the **difference** in the apparent separation of the **lower** edges of the leaves before the exposure and after the exposure. An example: If the reading before the exposure is 18 mm and the reading after the exposure is 6 mm, the **difference** in readings is 18 mm - 6 mm = 12 mm.

8. If an exposure results in a difference in readings of **less** than **2 mm**, recharge the KFM and expose it again for one of the **longer** time intervals listed. (If there appears to be **no** difference in the readings taken before and after an exposure for one minute, this does not prove there is absolutely no fallout danger.)

9. If an exposure results in the **reading** after the exposure being **less than 5 mm**, recharge the KFM and expose it again for one of the **shorter** time intervals listed.

10. Use the table attached to the KFM to find the **dose rate** (R/hr) during the time of exposure. The dose rate (R/hr) is found at the intersection of the vertical column of numbers under the time interval used and of the horizontal line of numbers that lists the calculated difference in readings at its left end.

TABLE USED TO FIND DOSE RATES (R/HR. FROM KFM READINGS

**DIFFERENCE BETWEEN THE READING BEFORE EXPOSURE AND THE READING AFTER EXPOSURE (8-PLY STANDARD FOIL LEAVES)*

DIFF.* IN READINGS	TIME INTERVAL OF AN EXPOSURE				
	15 SEC. R/HR	1 MIN. R/HR	4 MIN. R/HR	16 MIN. R/HR	1 HR. R/HR
2 mm	6.2	1.6	0.4	0.1	0.03
4 mm	12.	3.1	0.8	0.2	0.06
6 mm	19.	4.6	1.2	0.3	0.08
8 mm	25.	6.2	1.6	0.4	0.10
10 mm	31.	7.7	2.0	0.5	0.13
12 mm	37.	9.2	2.3	0.6	0.15
14 mm	43.	11.	2.7	0.7	0.18

An example: If the time interval of the exposure was **1 MIN.** and the difference in readings was **12 mm**, the

table shows that the **dose rate** during the time interval of the exposure was **9.2 R/HR** (9.2 roentgens per hour).

Another example: If the time interval of the exposure was **15 SEC.** and the difference in readings was **11 mm**, the table shows that the dose rate during the exposure was halfway between **31 R/HR** and **37 R/HR** that is, the **dose rate** was 34 R/hr.

11. Note in the table that if an exposure for one of the listed time intervals causes the **difference** in readings to be 2 mm or 3 mm, then an exposure 4 times as long reveals the same dose rate. An example: IF a 1 - min exposure results in a difference in readings of 2 mm, the table shows the dose rate was 1.6 R/hr; then if the KFM is exposed for 4 minutes at this same dose rate of 1.6 R/hr, the table shows that the resultant difference in readings is 8 mm.

    The longer exposure results in a more accurate determination of the dose rate.

12. If the dose rate is found to be greater than 0.2 R/hr and time is available, recharge the KFM and repeat the dose-rate measurement -- to avoid possible mistakes.

C. Calculating the **Dose Received**

The **dose** of fallout radiation -- that is, the **amount** of fallout radiation received -- determines the harmful effects on men and animals. Being exposed to a high **dose rate** is not always dangerous -- provided the exposure is short enough to result in only a small **dose** being received. For example, if the **dose rate** outside an excellent fallout shelter is 1200 R/hr and a shelter occupant goes outside for 30 seconds, he would be exposed for 1/2 of 1 minute, or 1/2 of 1/60 of an hour, which equals 1/120 hour. Therefore, since the dose he would receive if he stayed outside for 1 hour would be 1200 R, in 30 seconds he would receive 1/120 of 1200, which equals 10 R (1200 R divided by 120 = 10 R). A total daily **dose** of 10 R (10 roentgens) will not cause any symptoms if it is not repeated day after day for a week or more.

In contrast, if the average dose rate of an area were found to be 12 R/hr and if a person remained exposed in that particular area for 24 hours, he would receive a **dose** of 288 R (12 R/hr x 24 hr = 288 R). Even assuming that this person had been exposed previously to very little radiation, there would still be a serious risk that this 288 R **dose** would be fatal under the difficult conditions that would follow a heavy nuclear attack.

Another example: Assume that three days after an attack the occupants of a dry, hot cave giving almost complete protection against fallout are in desperate need of water. The dose rate outside is found to be 20 R/hr. To backpack water from a source 3 miles away is estimated to take 2-1/2 hours. The cave occupants estimate that the water backpackers will receive a dose in 2-1/2 hours of 50 R (2.5 hr x 20 R/hr = 50 R). A dose of 50 R will cause only mild symptoms (nausea in about 10% of persons receiving a 50 R dose) for persons who previously have received only very small doses. Therefore, one of the cave occupants makes a rapid radiation survey for about 1-1/2 miles along the proposed route, stopping to charge and read a KFM about every quarter of a mile. He finds no dose rates much higher than 20 R/hr.

So, the cave occupants decide the risk is small enough to justify some of them leaving shelter for about 2-1/2 hours to get water.

D. Estimating the **Dangers** from Different Radiation Doses

Fortunately, the human body -- if given enough time -- can repair most of the damage caused by radiation. An historic example: A healthy man accidently received a daily **dose** of 9.3 R (or somewhat more) of fallout-type radiation each day for a period of 106 days. His total accumulated **dose** was at least 1000 R. A dose of 1000 roentgens, if received in a few days, is almost three times the dose likely to kill the average man if he receives the whole dose in a few days and after a nuclear attack cannot get medical treatment adequate rest, etc. However, the only symptom this man noted was serious fatigue.

The occupants of a high-protection-factor shelter (such as a trench shelter covered with 2 or 3 feet of earth and having crawlway entrances) would receive less than 1/200 of the radiation dose they would receive outside. Even in most areas of very heavy fallout, persons who remain continuously in such a shelter would receive a total accumulated **dose** of less than 25 R in the first day after the attack, and less than 100 R in the first two weeks. At the end of the first two weeks, such shelter occupants could start working outside for an increasing length of time each day, receiving a **daily dose** of no more than **6 R** for up to two months without being sickened.

To control radiation exposure in this way, each shelter must have a fallout meter, and a daily record must be kept of the approximate total dose received each day by every shelter occupant, both while inside and outside the shelter. The long-term penalty which would result from a dose of 100 R received within a few weeks is much less than many Americans fear. If 100 average persons received an external dose of 100 R during and shortly after a nuclear attack, the studies of the Japanese A-bomb survivors indicate that no more than one of them is likely to die during the following 30 years as a result of this 100 R radiation dose. These delayed radiation deaths would be due to leukemia and other cancers. In the desperate crisis period following a major nuclear attack, such a relatively small shortening of life expectancy during the following 30 years should not keep people from starting recovery work to save themselves and their fellow citizens from death due to lack of food and other essentials.

A healthy person who previously has received a total accumulated dose of no more than 100 R distributed over a 2-week period should realize that:

100 R, even if all received in a day or less, is unlikely to require medical care--provided during the next 2 weeks a total additional dose of no more than a few R is received.

350 R received in a few days or less is likely to prove fatal after a large nuclear attack when few survivors could get medical care, sanitary surroundings, a well-balanced diet, or adequate rest.

600 R received in a few days or less is almost certain to cause death within a few days.

E. Using a KFM to Reduce the Doses Received Inside a Shelter

Inside most shelters, the dose received by an occupant varies considerably, depending on the occupant's location. For example, inside an expedient covered-trench shelter the dose rate is higher near the entrance than in the middle of the trench. In a typical basement shelter the best protection is found in one corner. Especially during the first several hours after the arrival of fallout, when the dose rates and doses received are highest, shelter occupants should use their fallout meters to determine where to place themselves to minimize the doses they receive. They should use available tools and materials to reduce the doses they receive, especially during the first day, by digging deeper (if practical) and reducing the size of openings by partially blocking them with earth, water containers, etc. -- while maintaining adequate ventilation. To greatly reduce the slight risk of fallout particles entering the body through nose or mouth, shelter occupants should cover nose and mouth with a towel or other cloth while the fallout is being deposited outside their shelter, if at the same time ventilating air is being blown or pumped through their shelter.

The air inside an occupied shelter often becomes very humid. If a good flow of outdoor air is flowing into a shelter -- especially if pumped by briefly operating a KAP or other ventilating pump -- a KFM usually can be charged at the air intake of the shelter room without putting it inside a dry-bucket. However, if the air to which a KFM is exposed has a relative humidity of 90% or higher, the instrument cannot be charged, even by quickly unrolling a roll of tape.

In extensive areas of heavy fallout, the occupants of most home basements, that provide inadequate shielding against heavy fallout radiation, would be in deadly danger. By using a dependable fallout meter, occupants would find that persons lying on the floor in certain locations would receive the smallest doses, and that, if they improvise additional shielding in these locations, the doses received could be greatly reduced. Additional shielding can be provided by making a very small shelter inside the basement where the dose rate is found to be lowest. Furniture, boxes, etc. can be used for walls, doors for the roof, and water containers, books, and other heavy objects for shielding -- especially on the roof. Or, if tools are available, breaking through the basement floor and digging a shelter trench will greatly increase available protection against radiation. If a second expedient ventilating pump, a KAP, is made and used as a fan, such an extremely cramped shelter inside a shelter usually can be occupied by several times as many persons.

END OF INSTRUCTIONS

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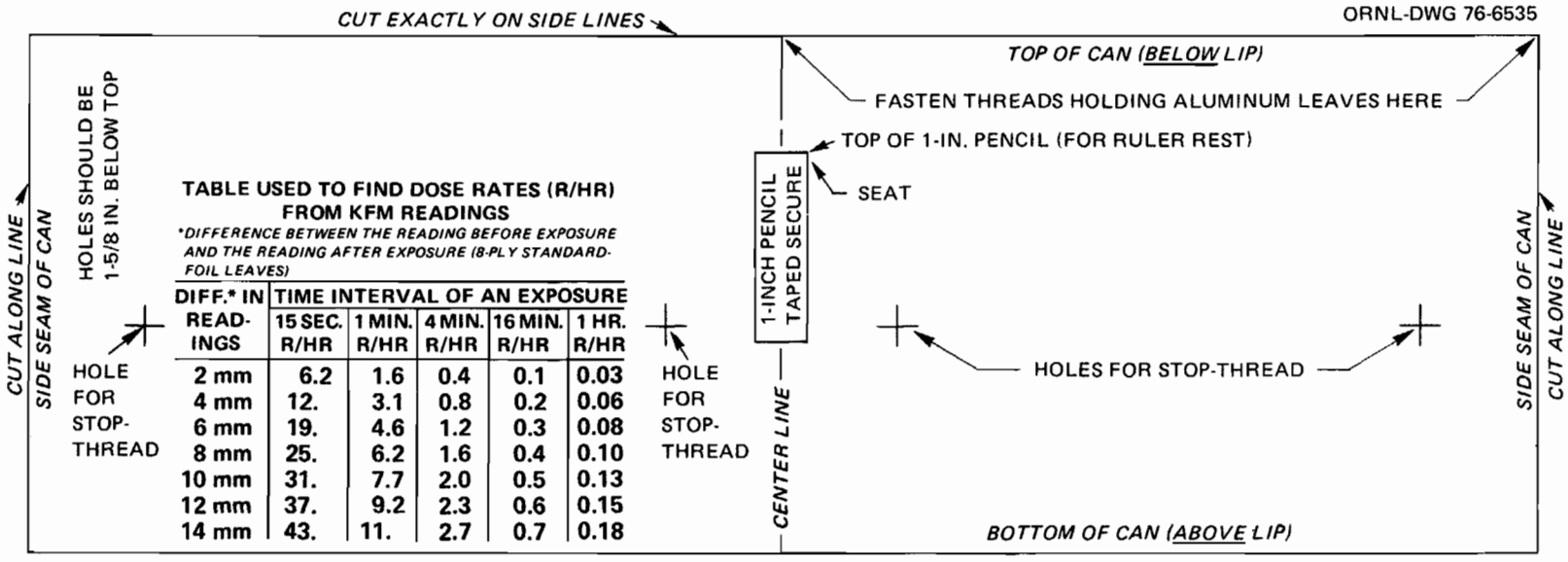
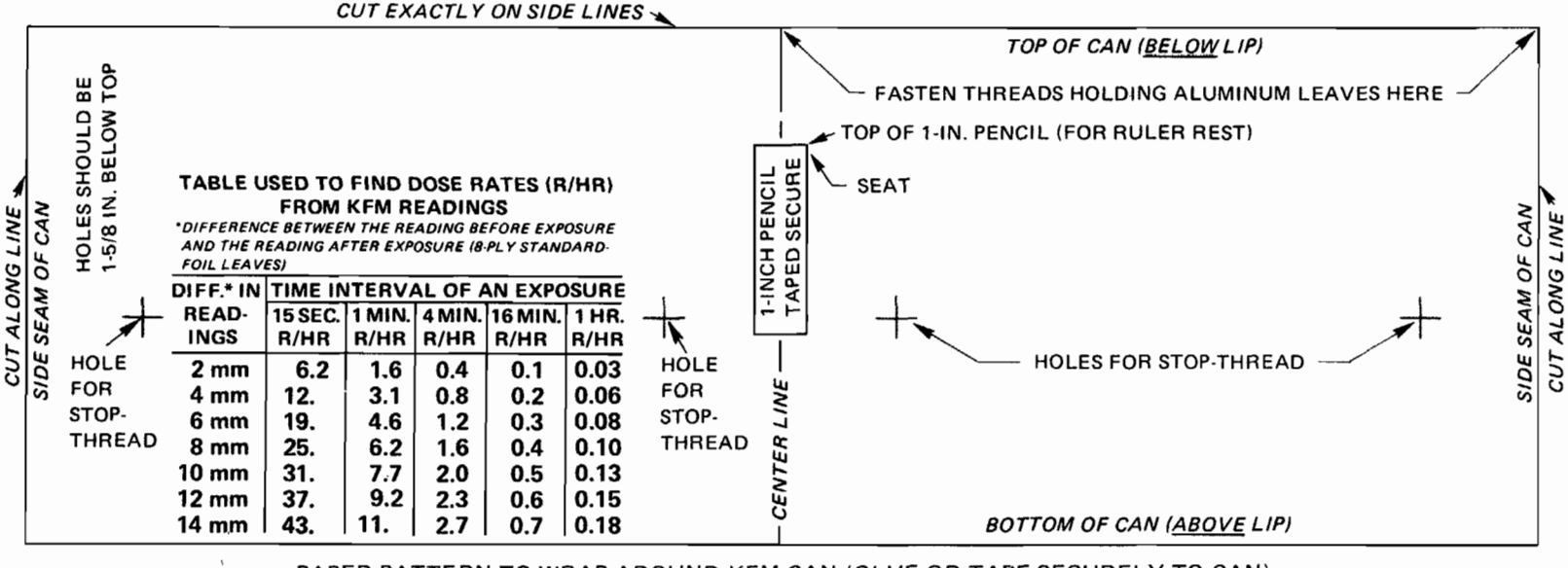


TABLE USED TO FIND DOSE RATES (R/HR) FROM KFM READINGS

**DIFFERENCE BETWEEN THE READING BEFORE EXPOSURE AND THE READING AFTER EXPOSURE (8-PLY STANDARD-FOIL LEAVES)*

DIFF.* IN READINGS	TIME INTERVAL OF AN EXPOSURE				
	15 SEC. R/HR	1 MIN. R/HR	4 MIN. R/HR	16 MIN. R/HR	1 HR. R/HR
2 mm	6.2	1.6	0.4	0.1	0.03
4 mm	12.	3.1	0.8	0.2	0.06
6 mm	19.	4.6	1.2	0.3	0.08
8 mm	25.	6.2	1.6	0.4	0.10
10 mm	31.	7.7	2.0	0.5	0.13
12 mm	37.	9.2	2.3	0.6	0.15
14 mm	43.	11.	2.7	0.7	0.18



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PAPER PATTERN TO WRAP AROUND KFM CAN (GLUE OR TAPE SECURELY TO CAN)

CUT OUT THESE PATTERNS, EACH OF WHICH IS THE EXACT SIZE FOR A KFM.

CAUTION: XEROX COPIES OF THESE PATTERNS WILL BE TOO LARGE.

PATTERN PAGE (A)

INSTRUCTIONS
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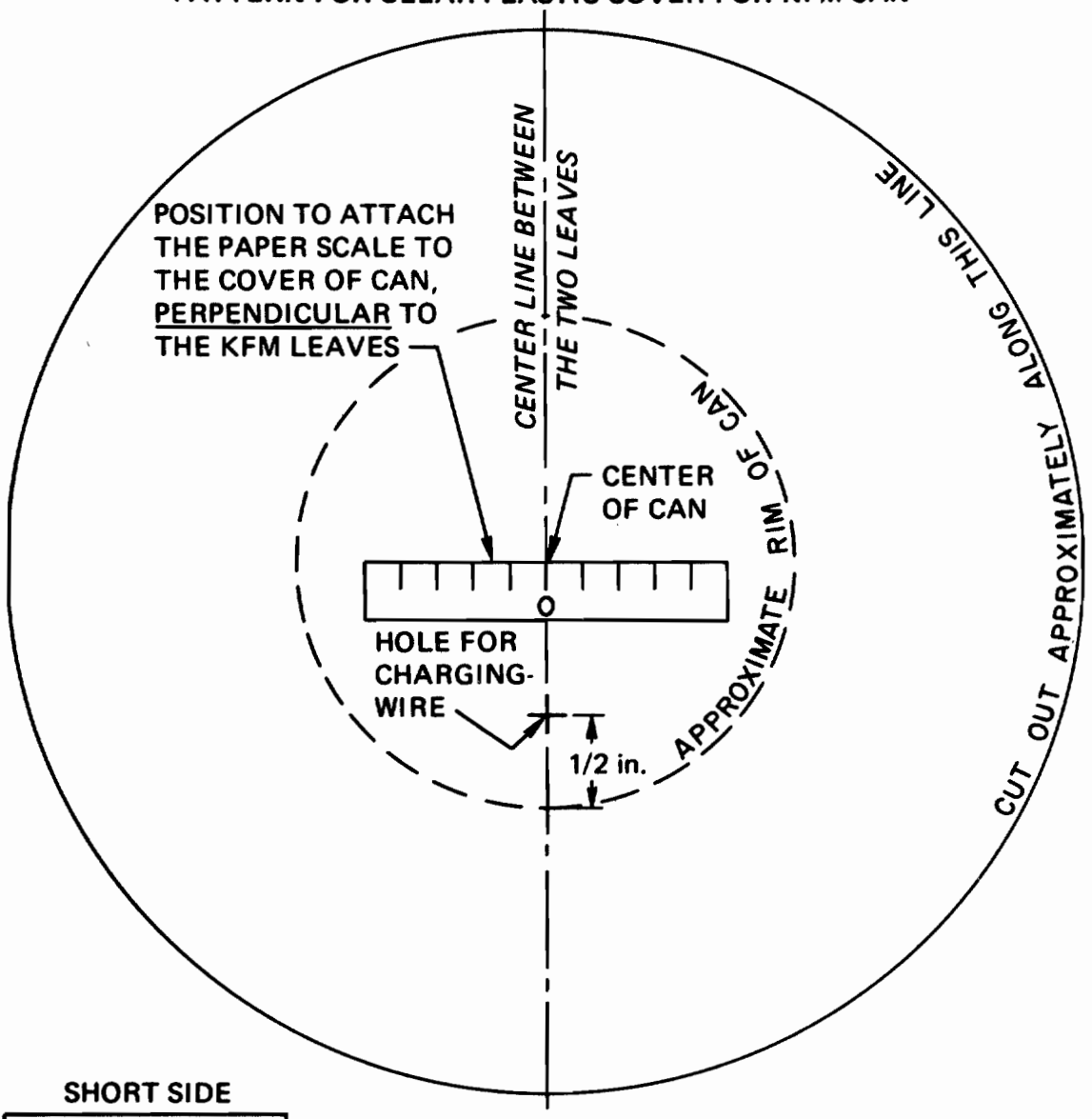
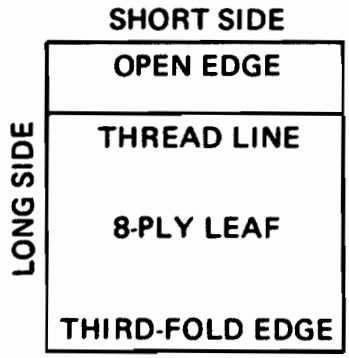
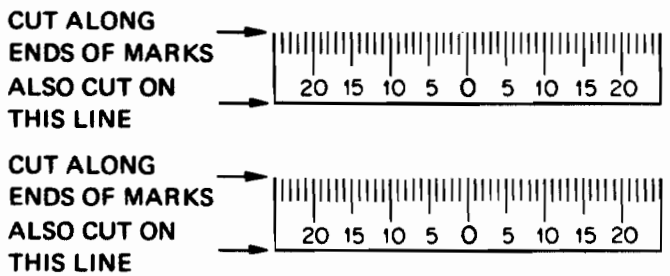
PATTERN FOR CLEAR-PLASTIC COVER FOR KFM CAN



SAVE THESE PATTERNS FOR PRINTING REPRODUCTIONS OF THE COMPLETE INSTRUCTIONS DURING A POSSIBLE CRISIS. FOR PRE-CRISIS PRACTICE CUT OUT PATTERNS FROM THE TWO EXTRA PATTERN-PAGES AT THE END OF THESE INSTRUCTIONS.



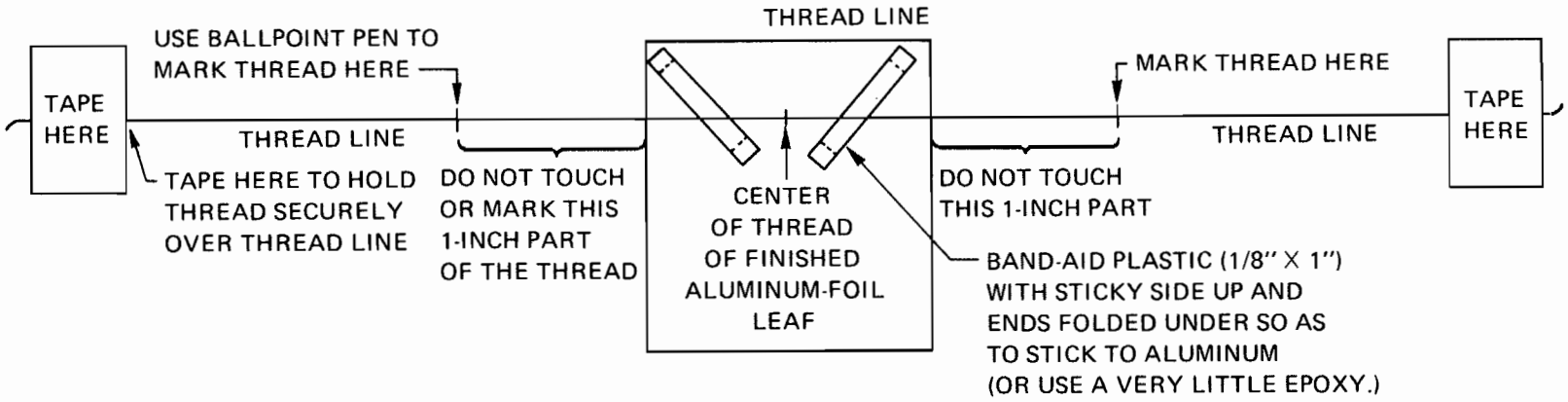
FINISHED-LEAF PATTERN
(CUT OUT EXACTLY ON SIDE LINES)



PAPER SCALE (TO BE CUT OUT)

CAUTION: XEROX COPIES OF THE FINISHED-LEAF AND THE SCALE PATTERNS WILL BE SLIGHTLY TOO LARGE.

COVER THE TWO "TAPE HERE" RECTANGLES WITH SAME-SIZED PIECES OF TAPE, TO KEEP FROM TEARING THE PAPER WHEN REMOVING OTHER PIECES OF TAPE. THEN, USING TWO OTHER PIECES OF TAPE THIS SAME SIZE, TAPE THE THREAD ONTO THIS GUIDE SHEET, AND LATER ATTACH A LEAF TO THE TAPED DOWN THREAD.



WARNING: The parts of the thread that will be inside the can and on which the leaf will be suspended must serve to insulate the high-voltage electrical charges to be placed on the leaf. Therefore, the suspended parts of the thread must be kept very clean.

INSTRUCTIONS
EXTRA PAGE

REMINDERS FOR OPERATORS

THE DRYING AGENT INSIDE A KFM IS O.K. IF, WHEN THE CHARGED KFM IS NOT EXPOSED TO RADIATION, ITS READINGS DECREASE BY 1 MM OR LESS IN 3 HOURS.

READING: WITH THE READING EYE 12 INCHES VERTICALLY ABOVE THE SEAT, NOTE ON THE MM SCALE THE SEPARATION OF THE LOWER EDGES OF THE LEAVES. IF THE RIGHT LEAF IS AT 10 MM AND THE LEFT LEAF IS AT 7 MM, THE KFM READS 17 MM. NEVER TAKE A READING WHILE A LEAF IS TOUCHING A STOP-THREAD. NEVER USE A KFM READING THAT IS LESS THAN 5MM.

FINDING A DOSE RATE: IF BEFORE EXPOSURE A KFM READS 17 MM AND IF AFTER A 1-MINUTE EXPOSURE IT READS 5 MM, THE DIFFERENCE IN READINGS IS 12 MM, THE ATTACHED TABLE SHOWS THE DOSE RATE WAS 9.6 R/HR DURING THE EXPOSURE.

FINDING A DOSE: IF A PERSON WORKS OUTSIDE FOR 3 HOURS WHERE THE DOSE RATE IS 2 R/HR, WHAT IS HIS RADIATION DOSE? ANSWER: 3 HR x 2 R/HR = 6 R.

FINDING HOW LONG IT TAKES TO GET A CERTAIN R DOSE: IF THE DOSE RATE IS 1.6 R/HR OUTSIDE AND A PERSON IS WILLING TO TAKE A 6 R DOSE, HOW LONG CAN HE REMAIN OUTSIDE? ANSWER:

6 R ÷ 1.6 R/HR = 3.75 HR =

3 HOURS AND 45 MINUTES.

FALLOUT RADIATION GUIDES FOR A HEALTHY PERSON NOT PREVIOUSLY EXPOSED TO A TOTAL RADIATION DOSE OF MORE THAN 100 R DURING A 2-WEEK PERIOD:

6 R PER DAY CAN BE TOLERATED FOR UP TO TWO MONTHS WITHOUT LOSING THE ABILITY TO WORK.

100 R IN A WEEK OR LESS IS NOT LIKELY TO SERIOUSLY SICKEN.

350 R IN A FEW DAYS IS LIKELY TO PROVE FATAL UNDER POST-ATTACK CONDITIONS.

600 R IN A WEEK OR LESS IS ALMOST CERTAIN TO CAUSE DEATH WITHIN A FEW WEEKS.

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INSTRUCTIONS
EXTRA PAGE

Appendix D
Expedient Blast Shelters

INCREASING IMPORTANCE

The majority of urban and suburban Americans would need blast shelters to avoid death or injury if they did not evacuate before an all-out nuclear attack. As nuclear arsenals continue to grow, an increasing majority would need the protection of blast shelters. As much as 3% of the total area of the 48 states could be subjected to blast severe enough to destroy or damage homes—depending on targeting, weapon reliability, etc. If blast shelters affording protection up to the 15-pounds-per-square-inch (15 psi) overpressure range were available and occupied, people could survive the blast, fire, and radiation effects in about 85% of this extensive threatened area. Blast tests have indicated that the Small-Pole Shelter (the most blast-resistant of the earth-covered shelters described in Appendix A) should enable occupants to survive all blast effects at the 50-psi overpressure range—if built with the blast doors and other protective features described on the following pages. Calculations show that it also would give adequate protection against the intense initial nuclear radiation if improved in the ways outlined later in this appendix.

The life-saving potential of well designed, well built blast shelters is a demonstrated fact. Millions of Americans living in high-risk areas would be able to build expedient blast shelters within only a few days—provided they make some preparations before a crisis arises. The following information is given in the hope of encouraging more Americans to make preparations for blast protection. Also, it may serve to increase the number who realize the need for *permanent* blast shelters in high-risk blast areas.

Some informed citizens—particularly those who live near large cities or in their outer suburbs—may choose to build earth-covered expedient blast shelters in their backyards, rather than to evacuate. Going into a strange area and trying to build or find good shelter and other essentials of life would entail risks that many people might hesitate to take, particularly if they live outside the probable areas of severe blast damage. For such citizens, the best decision might be to stay at home, build earth-covered expedient blast shelters, supply them with the essentials for long occupancy, and remain with their possessions.

Persons in 15-psi blast shelters would not be injured by blast, fire, or radiation effects from a 1-megaton surface burst $1\frac{1}{2}$ miles away, or from a 20-megaton surface burst 4 miles away. If an attack occurs, the area in which persons in 15-psi blast shelters would be killed by blast, fire, or radiation would be only about $\frac{1}{7}$ as large as the area in which most people sheltered in average homes would die from blast and fire effects alone.

The following descriptions of the characteristics and components of expedient blast shelters should enable many readers to use locally available materials to provide at least 15-psi blast protection. Pre-crisis preparations are essential, as well as the ability to work very hard for two to four days. (Field-tested instructions are not yet available; to date only workers who were supervised have built expedient blast shelters.[5])

PRACTICALITY OF EXPEDIENT BLAST SHELTERS

At Hiroshima and Nagasaki, simple wood-framed shelters with about 3 feet of earth over wooden roofs were undamaged by blast effects in areas where substantial buildings were demolished.[4]

Figure D.1 shows a Hiroshima shelter that people with hand tools could build in a day, if poles or timber were available. This shelter withstood blast and fire at an overpressure range of about 65 psi. Its narrow room and a 3-foot-thick earth cover brought about effective earth arching; this kept its yielding wooden frame from being broken.

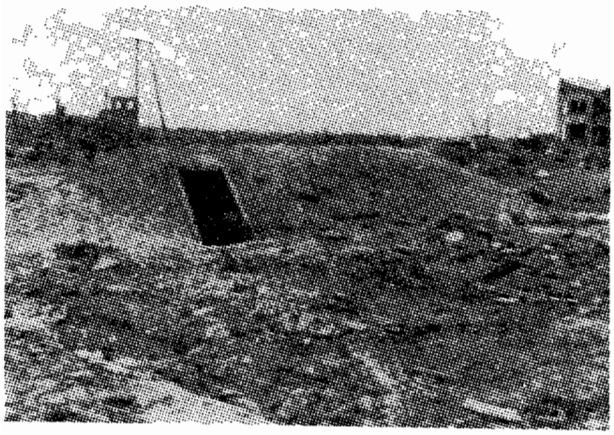

Fig. D.1. A small, earth-covered backyard shelter with a crude wooden frame—undamaged, although only 300 yards from ground zero at Hiroshima.

Although the shelter itself was undamaged, its occupants would have been fatally injured because the shelter had no blast door. The combined effect of blast waves, excessive pressure, blast wind, and burns from extremely hot dust blown into the shelter (the popcorning effect) and from the heated air would have killed the occupants. For people to survive in areas of severe blast, their shelters must have strong blast doors.

In nuclear weapons tests in the Nevada desert, box-like shelters built of lumber and covered with sandy earth were structurally undamaged by 10- to 15-psi blast effects. However, none had blast doors, so occupants of these open shelters would have been injured by blast effects and burned as a result of the popcorning effect. Furthermore, blast winds blew away much of the dry, sandy earth mounded over the shelters for shielding; this resulted in inadequate protection against fallout radiation.

Twelve different types of expedient shelters were blast-tested by Oak Ridge National Laboratory during three of Defense Nuclear Agency's blast tests.[5] Two of these tests each involved the detonation of a million pounds or more of conventional explosive; air-blast effects equivalent to those from a 1-kiloton nuclear surface burst were produced by these chemical explosions.

Several of these shelters had expedient blast doors which were closed during the tests. Figure D.2 shows the undamaged interior of the best expedient blast shelter tested prior to 1978, an improved version of the Small-Pole Shelter described in Appendix A. Its two heavy plywood blast doors excluded practically all blast effects; the pressure inside rose only to 1.5 psi—an overpressure not nearly high enough to break eardrums. The only damage was to the expedient shelter-ventilating pump (a KAP) in the stoop-in entryway. Two men worked about 5 minutes to replace the 4 flap-valves that were blown loose.

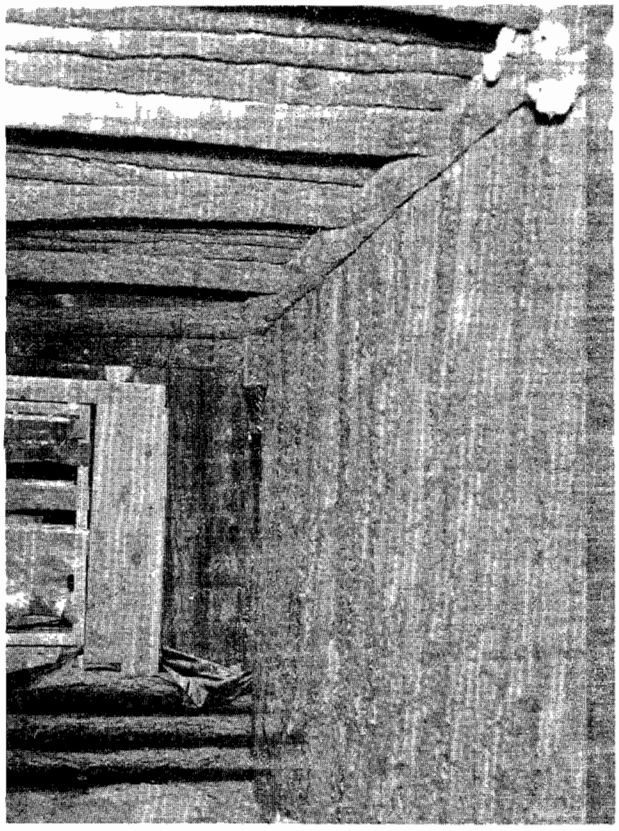

Fig. D.2. Undamaged interior of a Small-Pole Shelter after blast testing at the 53-psi overpressure range. Large buildings would have been completely demolished.

When blast-tested at 5-psi overpressure, not even the weakest covered-trench shelters with unsupported earth walls (described in Appendix A) were damaged structurally. However, if the covering

earth were sandy and dry and if it were exposed to the blast winds of a megaton explosion at the 5-psi overpressure range, so much earth would be blown away that the shelter would give insufficient protection against fallout radiation. Much of the dry, shielding earth mounded over some of the above-ground shelters was, in fact, removed by the blast winds of these relatively small test explosions, even at the lower overpressure ranges at which homes would be wrecked. In contrast, in blast tests where the steeply mounded earth was damp, little blast-wind erosion resulted. (The reader should remember that even if shelters without blast doors are undamaged, the occupants are likely to suffer injuries.)

CONSTRUCTION PRINCIPLES

Millions of Americans—if given good instructions, strong motivation, and several days to work—should be able to build blast shelters with materials found in many rural areas and suburban neighborhoods. During a crisis, yard trees could be cut down for poles and sticks, and a garage or part of a house could be torn down for lumber. Many average citizens could build expedient blast shelters if they learn to:

- **Utilize earth arching by making a yielding shelter.** The remarkable protection that earth arching gives to those parts of a shelter designed to use it is illustrated by Fig. D.3.

This picture shows the unbroken roof of a 4-foot-wide Pole-Covered Trench Shelter that was built in rock-like soil and blast tested where the blast pressure outside was 53 psi. Its strong blast doors prevented the blast wave from entering. Without the protection of earth arching that developed in the 5 feet of earth cover over the yielding roof poles, the poles would have been broken like straws. In contrast, the ground shock and earth pressure produced by 1-kiloton blast effects almost completely collapsed the unsupported, rock-like earth walls.

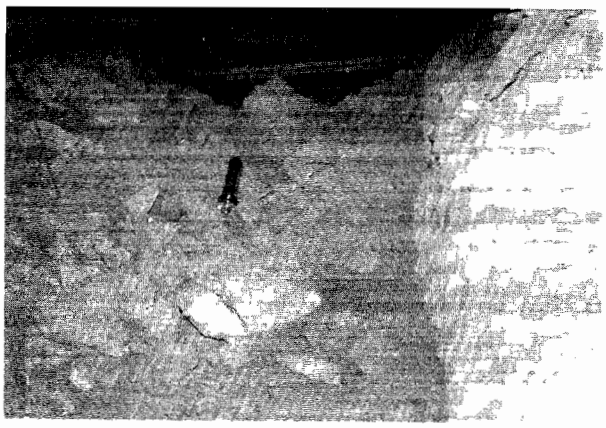

Fig. D.3. Effective earth arching in the earth covering of this 4-ft-wide Pole-Covered Trench Shelter prevented a single pole from being broken by blast forces that exerted a downward force of 53 psi (over $3\frac{1}{2}$ tons per square foot) on the overlying earth.

Fig. D.4. Post-blast interior of an Above-ground, Door-Covered Shelter that survived 1-kiloton blast effects at the 5.8-psi overpressure range. The shelter walls were made of bedsheets containing earth, as described in Appendix A.

Figure D.4 also indicates the effectiveness of earth arching. This photo shows the roof of a small, earth-covered fallout shelter, as it appeared after surviving blast effects severe enough to demolish most homes. The roof was made of light, hollow-core, interior doors and looks as though it had been completely broken. In fact, only the lower sheets of $\frac{1}{8}$-inch-thick veneer of the hollow-core interior doors were broken. (These breaks were caused by a faulty construction procedure—a front-end loader had dumped several tons of earth onto the uncovered doors.) The upper $\frac{1}{8}$-inch-thick sheets of veneer were bowed downward, unbroken, until an earth arch formed in the 2-foot-thick earth covering and prevented the thin sheets from being broken. Earth arching also prevented this roof from being smashed in by blast overpressure that exerted a pressure of 5.8 psi (835 pounds per square foot) on the surface of the earth mounded over this open shelter. (See Appendix A for details of construction.)

- **Make shelters with the minimum practical ceiling height and width.** Most of the narrow

covered-trench shelters used by tens of thousands of Londoners during the World War II blitz were built with only 4½-foot ceilings, to maximize blast protection and minimize high water-table problems. These shelters were found to be among the safest for protection against nearby explosions. The Chinese also have a good understanding of this design principle and skillfully utilize the protection provided by earth arching. A Chinese civil defense handbook states: "... the height and width of tunnel shelters should be kept to the minimum required to accommodate the sheltering requirements," and "The thicker the protective layer of earth, the greater the ability to resist blast waves."[21]

- **Shore earth walls to prevent their caving in as a result of ground shock and earth pressure.** Most unshored (that is, unsupported) earth walls are partially collapsed by ground shock at much lower blast overpressures than those at which a flexible roof protected by earth arching is damaged. Figure D.5 is a picture of a seated dummy taken by a high-speed movie camera mounted inside an unshored, Pole-Covered Trench Shelter of the Russian type tested at the 20-psi range. (A second dummy was obscured by blast-torn curtains made of blankets.) The shelter had an open stairway entryway, positioned at right angles to the stand-up-height trench and facing away from the targeted "city" so as to minimize the entry of blast waves and blast wind.

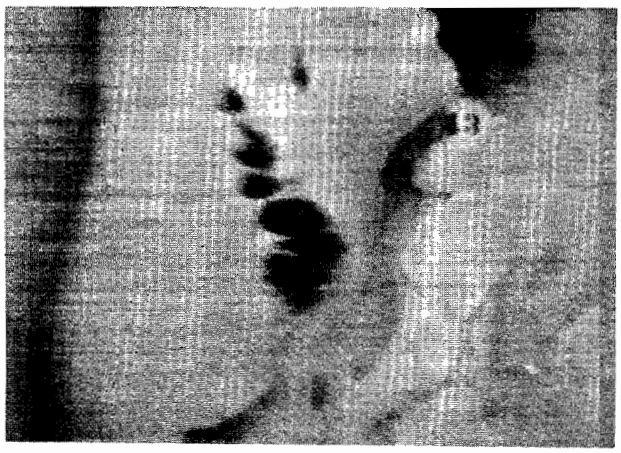

Fig. D.5. A dummy in an unshored Pole-Covered Trench Shelter as it is struck by collapsing rock-like earth walls. The photo also shows the shelter's blanket-curtains as they are torn and blown into the shelter by the 180-mph blast wind. (Immediately after this photo was taken, the dummies were hit by the airborne blast wave and blast wind. Outside, the blast wind peaked at about 490 mph.)

Figure D.6 is a post-blast view of the essentially undamaged earth-covered roof poles and the disastrously collapsed, unshored shelter walls of the Russian shelter tested at 20 psi.[21] Russian civil defense books state that unshored fallout shelters do not survive closer to the blast than the 7-psi overpressure range. This limitation was confirmed by an identical shelter tested at 7 psi; parts of its unshored walls were quite badly collapsed by the ground shock from an explosion producing merely 1-kiloton blast effects.

Fig. D.6. Dummies after ground shock from 1-kiloton blast effects at the 20-psi range had collapsed the rock-like walls of a hardened desert soil called caliche. The dummies' steel "bones" and "joints" prevented them from being knocked down and buried. The fallen caliche all around them kept them from being blown over by the air blast wave and 180-mph blast wind that followed.

Unsupported earth walls should be sloped as much as practical. The length and strength of available roofing material should be considered and, in order to attain effective earth arching, the thickness of the earth cover should be **at least** half as great as the distance between the edges of the trench.

The stability of the earth determines the proper method for shoring the walls of a trench shelter.

Methods for shoring both loose, unstable earth and firm, stable earth are described below:

*In loose, unstable earth such as sand, the walls of all underground shelters must be shored. First, an oversized trench must be dug with gently sloping sides. Next, the shoring is built, often as a freestanding, roofless structure. Then earth must be

backfilled around the shoring to a level a few inches higher than the uppermost parts of the shoring, as in Fig. D.7. Finally, the roof poles or planks must be placed so that they are supported only by the backfilled earth. Blast tests have indicated that a Pole-Covered Trench Shelter thus proportioned and lightly shored should protect its occupants against disastrous collapse of its walls at overpressure ranges up to 15 psi.

* **In firm, stable earth,** it is best first to dig a trench a few inches wider than 7 feet (the length of the roof poles) and 1 foot deep. Next, dig the part to be shored, down the center of this shallow trench, using the dimensions given for the shoring in Fig. D.7. The trench walls should be sloped and smoothed quite accurately, so that the shoring can be tightened against the earth. If the shoring does not press tightly against the trench walls, large wedges of earth may be jarred loose, hit the shoring, and cause it to collapse.

A different, comparatively simple way to tighten shoring is indicated by Fig. D.8. This sketch shows a 4-pole frame designed to be installed every $2\frac{1}{2}$ feet along a trench in stable earth and to be tightened against trench-wall shoring with the same dimensions as those shown in Fig. D.7. Note that the two horizontal brace poles have shallow "V" notches

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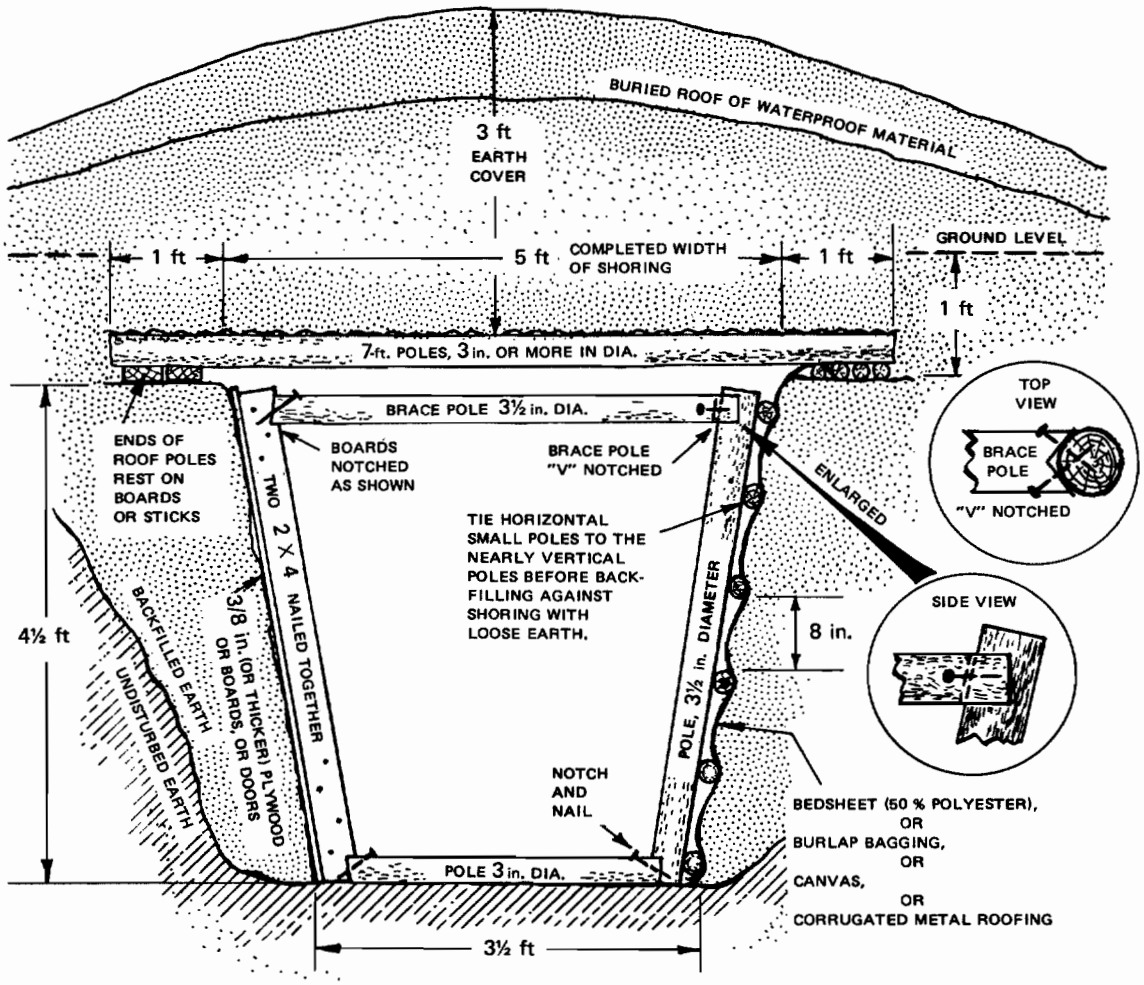

Fig. D.7. An illustration of several ways to shore a trench in unstable earth, using various materials. A 4-piece frame (consisting of 4 poles, or 4 boards, installed as shown above) should be installed every $2\frac{1}{2}$ feet along the length of the trench, including the horizontal parts of the entryways. All parts of the shoring should be at least 2 inches below the roof poles, so that the downward forces on the roof will press only on the earth.

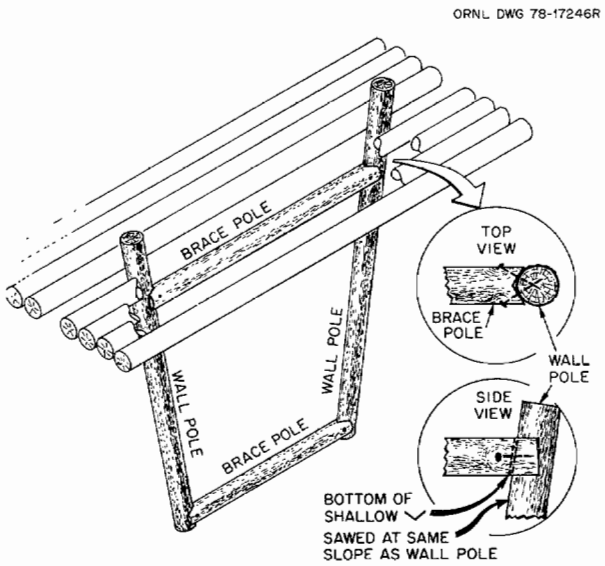

Fig. D.8. A 4-pole frame designed so that it can be tightened against the shoring materials that must press firmly against the walls of a trench dug in stable earth. (In this sketch, the middle sections of three poles have been removed, so that the upper brace pole may be seen more clearly.)

sawed in both ends. If these brace poles are driven downward when positioned as shown, the two wall poles are forced outward against the shoring materials placed between them and the earth walls. An upper brace pole should be cut to the length needed to make it approximately the same height as the roof poles on each side of it (no higher) after the shoring is tightened. Finally, each "V"-notched end should be nailed to its wall pole.

Light, yielding poles can serve simultaneously both to roof and to shore a shelter. A good example is the Chinese "Man" Shelter illustrated in Fig. D.9, requiring comparatively few poles to build.[21] This shelter is too cramped for long occupancy, and its unshored, lower earth walls can be squeezed in by blast pressure. Therefore, it is not recommended if sufficient materials are available for building a well-shored, covered-trench shelter. It is described here primarily to help the reader understand the construction of similarly designed entryways, outlined later in this appendix. The room and the horizontal entryway of the model tested were made of $6\frac{1}{2}$-foot poles averaging only 3 inches in diameter. It had two vertical, triangular entries of ORNL design. Each was protected by an expedient triangular blast door made of poles. In Fig. D.9, note the two small horizontal poles at the top of the triangle, one tied inside and the other tied outside the triangle, to hold the wall poles together. Before covering this shelter with earth, a 6-inch-thick covering of small limbs was placed horizontally across the approximately 3-inch-wide spaces between the $6\frac{1}{2}$-foot wall poles; the limbs were then covered with bedsheets.

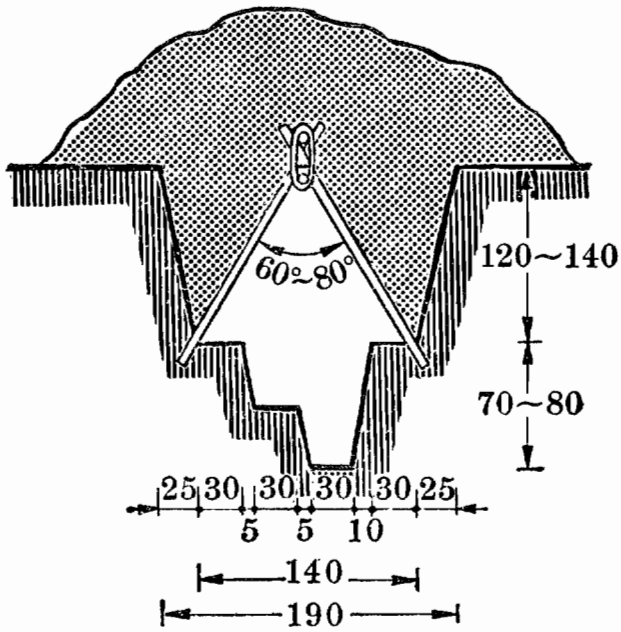

图 3-107 人字形骨架避弹所

Fig. D.9. Chinese "Man" Shelter tested at 20 psi, and undamaged because the thin poles yielded and were protected by earth arching. This drawing was taken from a Chinese civil defense manual. The dimensions are in centimeters.

When blast-tested in loose, unstable soil, the unsupported earth walls of the trench below the wall poles were squeezed in. The 12-inch width of the foot trench was reduced to as little as 4 inches by the short-duration forces produced by 0.2-kiloton blast effects at 50 psi. The much longer duration forces of a megaton explosion would be far more damaging to the shelter at lower overpressure ranges, due to destabilizing and squeezing-in unshored earth at depths many feet below ground level.

Calculations based on blast-test findings indicate that the unsupported earth walls of a shelter are likely to fail if the aboveground maximum overpressure is greater than 5 to 7 psi and this overpressure is caused by an explosion that is a megaton or more.

(Most homes would be severely damaged by the 3-psi blast effects from a 1-megaton or larger weapon. This damage would result one mile closer to ground zero of a 1-megaton surface burst than the distance at which the unshored earth walls of some shelters would be collapsed. For a 20-megaton surface burst, the corresponding reduction in distance would be about 2.7 miles.)

- **Build sufficiently long and strong entryways.** Blast shelters need longer horizontal entryways, taller vertical entryways, and thicker earth cover than do most fallout shelters; these are needed primarily for increased protection against high levels of initial nuclear radiation. The entryways of the Small-Pole Shelter described in Appendix A.3 (with the improvements for increased blast protection outlined in the following section of this appendix) afford protection against both blast and radiation up to the 50-psi overpressure range. However, these entryways require straight poles 14 feet long; these may be difficult to find or transport.

In contrast, both the horizontal and the vertical parts of the triangular entry pictured in Figs. D.10, D.11, and D.12 require only small-diameter, short poles. Triangular entries of this type were undamaged by 1-kiloton blast effects at the 20-psi overpressure range[5] and by 0.2-kiloton blast effects at 50 psi. This type of entry and its blast door (also triangular and made of short poles) can be used with a wide variety of expedient blast shelters and should withstand megaton blast effects at 25 psi. Therefore, their construction is described in considerable detail.

* **The horizontal part of a triangular entry:** If the Chinese "Man" Shelter shown in Fig. D.9 is made without excavating the unshored lower trench that forms its earth seats, it will serve as a horizontal, shored crawlway-entry affording blast protection up to at least the 25-psi overpressure range. Two horizontal entries, one at each end of the shelter, should be provided. Each entry should be 10 feet long. This length is needed to reduce the amount of initial nuclear radiation reaching the blast shelter room while assuring adequate through-ventilation. The outer part of such a horizontal entry is pictured in the background of Fig. D.10.

* **The vertical part of a triangular entry:** The *lower section* of the vertical part is made in a similar manner to the horizontal shelter shown in Fig. D.9. Figure D.10 shows $4\frac{1}{2}$-foot horizontal poles (1) forming a "V", with one end of each pole laid on top of the adjacent lower pole. The other ends of these poles (1) are pressed against the two pairs of vertical posts (2). (After this photo was taken, the tops of these two pairs of vertical posts were sawed off as

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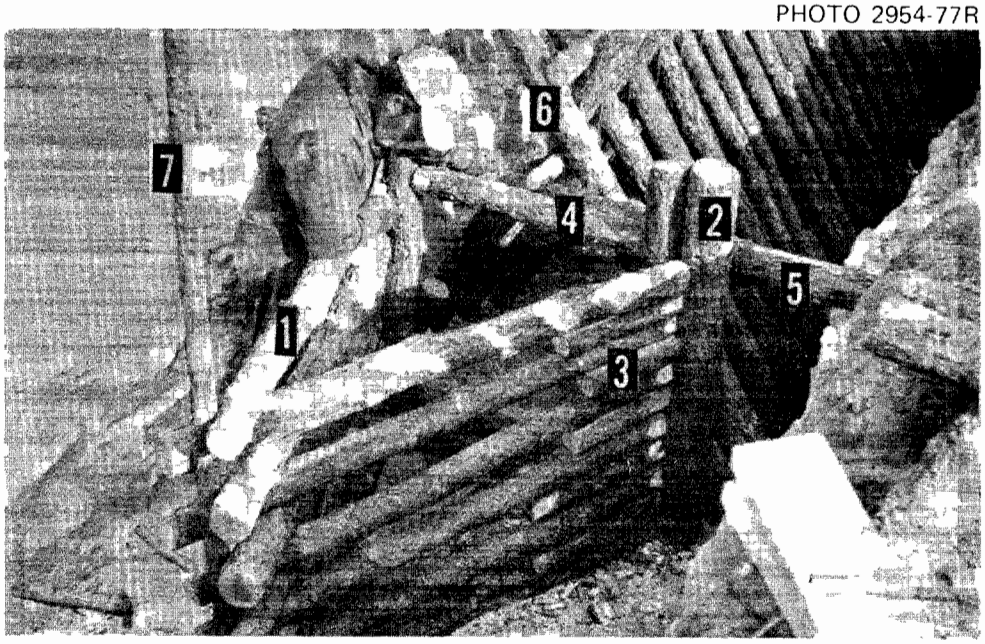
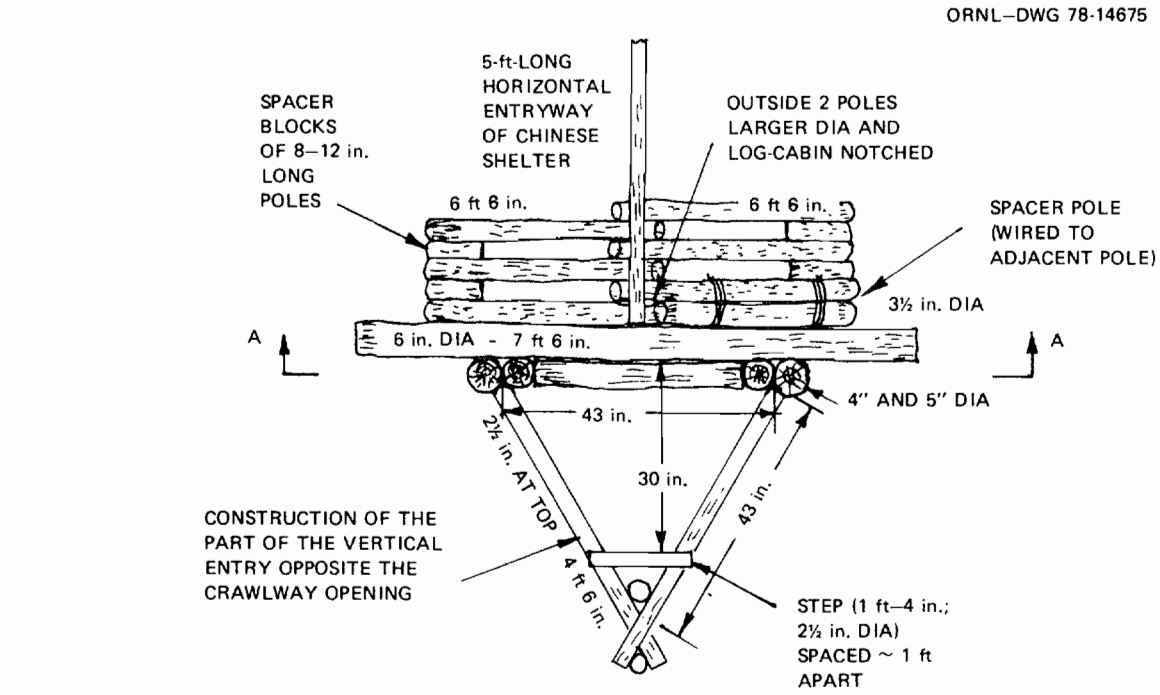


Fig. D.10. Uncompleted lower section of a vertical triangular entry.



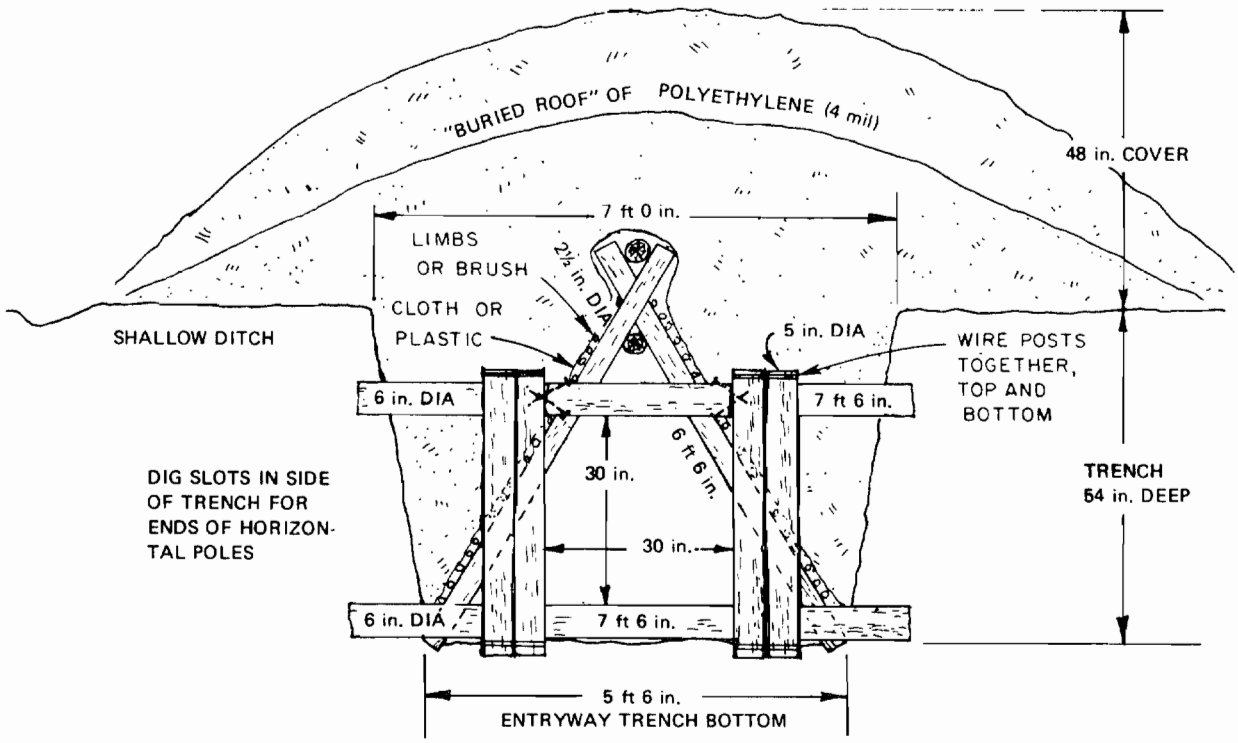


Fig. D.11. Lower part of a vertical triangular entry, showing its connection to the horizontal part of the shelter entry.

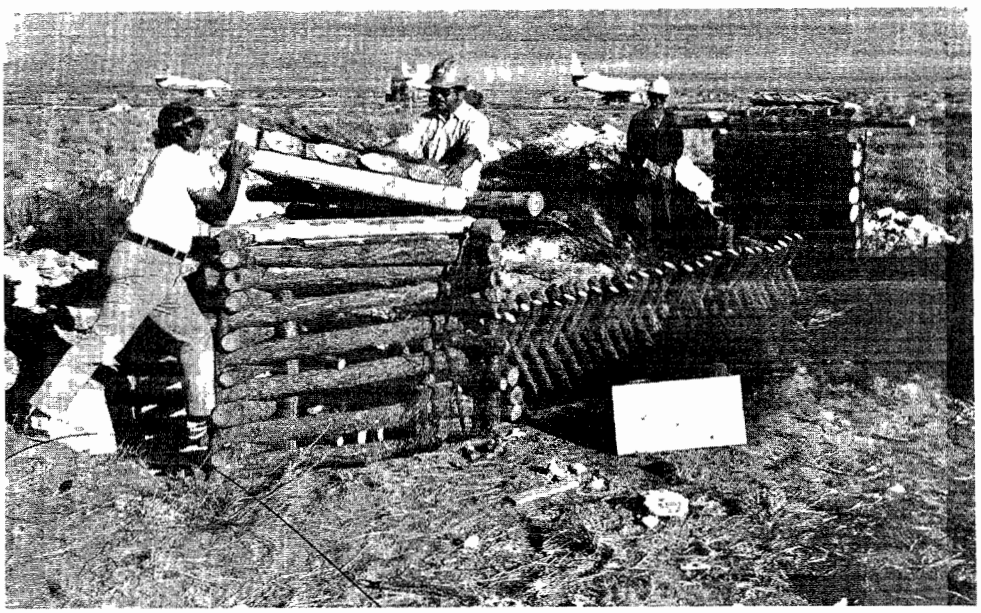


Fig. D.12. Completed frame of Chinese "Man" Shelter showing its two ORNL-designed entryways (one at each end) and triangular blast doors made of poles. Before covering the triangular vertical entries with earth, tree branches were placed vertically over the sides; the branches then were covered with bedsheets. Horizontal branches, also covered with bedsheets, were laid over the rest of the shelter frame. After being covered with earth, this shelter was subjected to 1-kiloton blast effects. Multiple earth arching over and around this yielding structure prevented both the small poles and the bedsheets from being damaged at 20 psi.

shown in Fig. D.11.) The $4^1/_2$-foot horizontal poles (1) were kept level by the short spacer-poles (3) that were wired or nailed in place.

Each pair of vertical posts (2) was securely wired together at top and bottom. The two pairs were held apart at top and bottom by two horizontal brace-poles toenailed in place to frame the rectangular 30-×30-inch crawlway "doorway" between the vertical entry and the horizontal entry. Only the upper pole (4) of these two 30-inch-long horizontal brace-poles is shown.

The two pairs of vertical posts (2) were positioned so that they pressed against two $7^1/_2$-foot horizontal poles (5); only the uppermost is shown. These in turn pressed against the outermost two poles (6) of the horizontal entry and against the earth in two slot-trenches dug in the sidewalls of the excavation. These two $7^1/_2$-foot poles (5) should be at least 6 inches in diameter.

Additional details of the lower section of this vertical triangular entry are given in Fig. D.11. If horizontal poles considerably larger in diameter than those illustrated are used, fewer poles are required and strength is increased. However, the space inside the entry is decreased unless the larger-diameter horizontal poles that form the "V" are made longer than $4^1/_2$ feet.

As shown on the left in Fig. D.10, a small, vertical pole (7) was placed in the small "V" between the outer ends of the horizontal poles that form the lower section of the vertical entry. After this photo was taken, a second small, vertical pole was positioned in the adjacent large "V", inside the entry. These two poles (7) were then tightly wired together so as to make a strong, somewhat yielding, outer-corner connection of the horizontal poles (1)—in the same way that the tops of the side-wall poles of the Chinese "Man" Shelter are bound together.

The **upper section** of the vertical part of this entry (the section above the tops of the two pairs of vertical posts shown in Fig. D.10 and Fig. D.11) is made by overlapping the ends of its nearly horizontal poles (Fig. D.12). These poles [marked with a (1) in Fig. D.10] were each 4 feet 6 inches long and varied uniformly in diameter from about $2^1/_2$ inches just above the two pairs of wired-together posts, to 4-inch diameters just below the triangular door frame of poles. The triangular-shaped blast door was hinged

to and closed against this door frame. The hinges were strips cut from worn auto tires, to be described shortly.

The upper section is formed by laying poles in a triangular pattern, ends crossing at the angles, with large ends and small ends placed so that the poles are as nearly horizontal as is practical. Each of its three corners is held together by strong wires that tightly bind an outside and an inside small vertical pole, in the same manner as the top of the Chinese "Man" Shelter (shown in Fig. D.9) is secured. (Instead of No. 9 soft steel wire, rope or twisted strips of strong fabric could be used.)

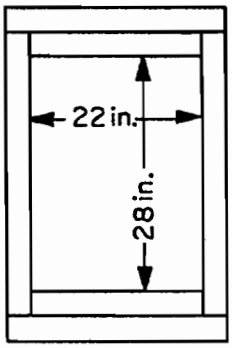
Before starting to install the upper section of a vertical triangular entry, the three outermost of the six small vertical poles that will hold the three corners together should be connected temporarily with three small horizontal poles. Connect them at the height of the door frame planned for the triangular blast door, and space them so as to be the same size as this door frame.

Next, all the horizontal poles should be laid out on the ground in the order of their increasing diameters. The triangular entry then should be started with the smallest poles at the base, with increasingly large-diameter poles used toward the top—so that the three pairs of small vertical poles will press securely against all the horizontal side poles of the entry.

To prevent the negative overpressure ("suction") phase of the blast from yanking out and carrying away the blast door and the upper part of the vertical entry to which it is hinged, the uppermost 4 or 5 horizontal poles of each of the three sides of the vertical entry should be wired or tied securely together. Rope or strips of strong cloth can be used if strong wire is not available.

Before placing earth around this lightly constructed blast-protective entry, the vertical walls must be covered to a thickness of about 6 inches with a yielding, crushable covering of limbs, brush, or innerspring mattresses. Limbs or brush should be placed in three layers, with the innermost layer at right angles to the underlying poles. The yielding thickness then is covered with strong cloth, such as 50% dacron bedsheets, or two thicknesses of 4-mil polyethylene film. This outermost covering keeps loose earth or sand from filling spaces inside the yielding layer or running into the entry. Thus protected, this vertical entry should be undamaged by 25-psi blast effects of megaton weapons.

A vertical blast-protective entry can also be made like a strong box, using 2-inch-thick boards. Such entries afford blast protection up to 50 psi if made as small as shown here and protected with yielding materials such as a 6-inch-thick layer of brush covered with strong cloth.



- **Install blast doors** to keep out airborne blast waves, blast wind, overpressure, blast-borne debris, burning-hot dust and air, and fallout.

A fast-rising overpressure of as little as 5 psi will break some people's eardrums. At overpressures of 15 to 20 psi, 50% of the people who are exposed will have their eardrums broken. However, persons near a shelter wall may have their eardrums broken by somewhat less than half of these unreflected overpressures. (Any wall may reflect blast waves and greatly increase overpressures near it.) Broken eardrums are not serious in normal times, but after a nuclear attack this injury is likely to be far more dangerous to persons in crowded shelters without effective medical treatment. Lung damage, that can result from overpressures as low as 10 to 12 psi, would also be more serious under post-attack conditions.

A blast door must withstand blast waves and overpressure. Not only must the door itself be sufficiently strong to withstand forces at least as great as those which the shelter will survive, but in addition the door frame and the entranceway walls must be equally as strong. The expedient blast door pictured in Fig. D.13 was made of rough boards, each a full 2 inches thick. It had a continuous row of hinges made of 18-inch-long strips cut from the treads of worn car tires.

The strips were nailed to the vertical poles on one side of the vertical entry. These and other details of construction are shown in Fig. D.14. Although the two center boards were badly cracked by the shock wave and overpressure at the 17-psi range, the door

Fig. D.13. Blast door surrounded by 4 blast-protector logs that were notched and nailed together. The wet, mounded soil had been compacted by the blast but not blown away.

pictured in Fig. D.13 afforded good protection against all blast effects from a surface explosion of a million pounds of TNT. In Fig. D.14, note the *essential,* strong tie-down attachment of the wires at the bottom of the vertical entry, to prevent the blast door from being yanked open by the negative pressure ("suction") that follows the overpressure.

Blast doors must be protected against reflected pressures from blast waves that could strike an edge of an unprotected door and tear it off its hinges. Note the blast-protector logs installed around the door pictured in Fig. D.14. When the door was closed, the tops of these four logs were about 2 inches higher than the door, thus protecting its edges on all sides.

The closed door must be prevented from rebounding like a spring and opening a fraction of a second after being bowed down by overpressure, or from being opened and perhaps torn off its hinges by the partial vacuum ("suction") that follows the overpressure phase. Figure D.14 gives the details of such a hold-down system for a blast door. Note that near the bottom of the vertical entry the 6 strong wires must encircle a horizontal pole that is flattened on one side and nailed to the vertical wall poles with at least a dozen 6-inch (60-penny) nails. Blast tests up to the 53-psi overpressure range have proved that this hold-down system works.[5]

Figure D.15 shows a blast door made of 5 thicknesses of $^3/_4$-inch exterior plywood, well glued and nailed together with $4^1/_2$-in. nails at 4-in. spacings. This door was protected by 4 blast-protector logs, each 8 feet long and about 8 inches in diameter. The logs were notched, nailed together, and surrounded with earth. For protection against ignition by the thermal pulse from an explosion, exposed wood and rubber should be coated with thick whitewash (slaked lime) or mud, or covered with aluminum foil.

An equally strong blast door and the door base upon which it closes can be made of poles. If poles are fresh-cut, they are easy to work with ax and saw. Figure D.16 shows the best blast-tested design. This door also had a continuous row of hinges made from worn auto tire treads. The pole to which the hinges were attached was 7 inches in diameter after peeling and had been flattened on its top and outer sides. The two other poles of the equal-sided triangle were 8 inches in diameter and had been flattened with an ax on the bottom, top, and inner sides. The three poles were each 55 inches long. They were notched and spiked together with 60-penny nails so that the door would close snugly on its similarly constructed base made of three stout poles. Other poles, at least 7 inches in diameter before being hewn so that they would fit together snugly, were nailed side-by-side on top of the three outer poles.

Many Americans have axes and would be able to cut poles, but not many know how to use an ax to hew flat, square sides on a pole or log. This easily acquired skill is illustrated by Fig. D.17. The worker should first fasten the pole down by nailing two small poles to it and to other logs on the ground. Figure D.17 shows a pole thus secured. When hewing a flat side, the worker stands with his legs spread far apart, and repeatedly moves his feet so that he can look almost straight down at where his ax head strikes. First, vertical cuts with a *sharp* ax are made about 3 or 4 inches apart and at angles of about 45° to the surface of the pole, for the length of the pole. These multiple cuts should be made almost as deep as is needed to produce a flat side of the desired width. Then the worker, again beginning at the starting end, should cut off long strips, producing a flat side.

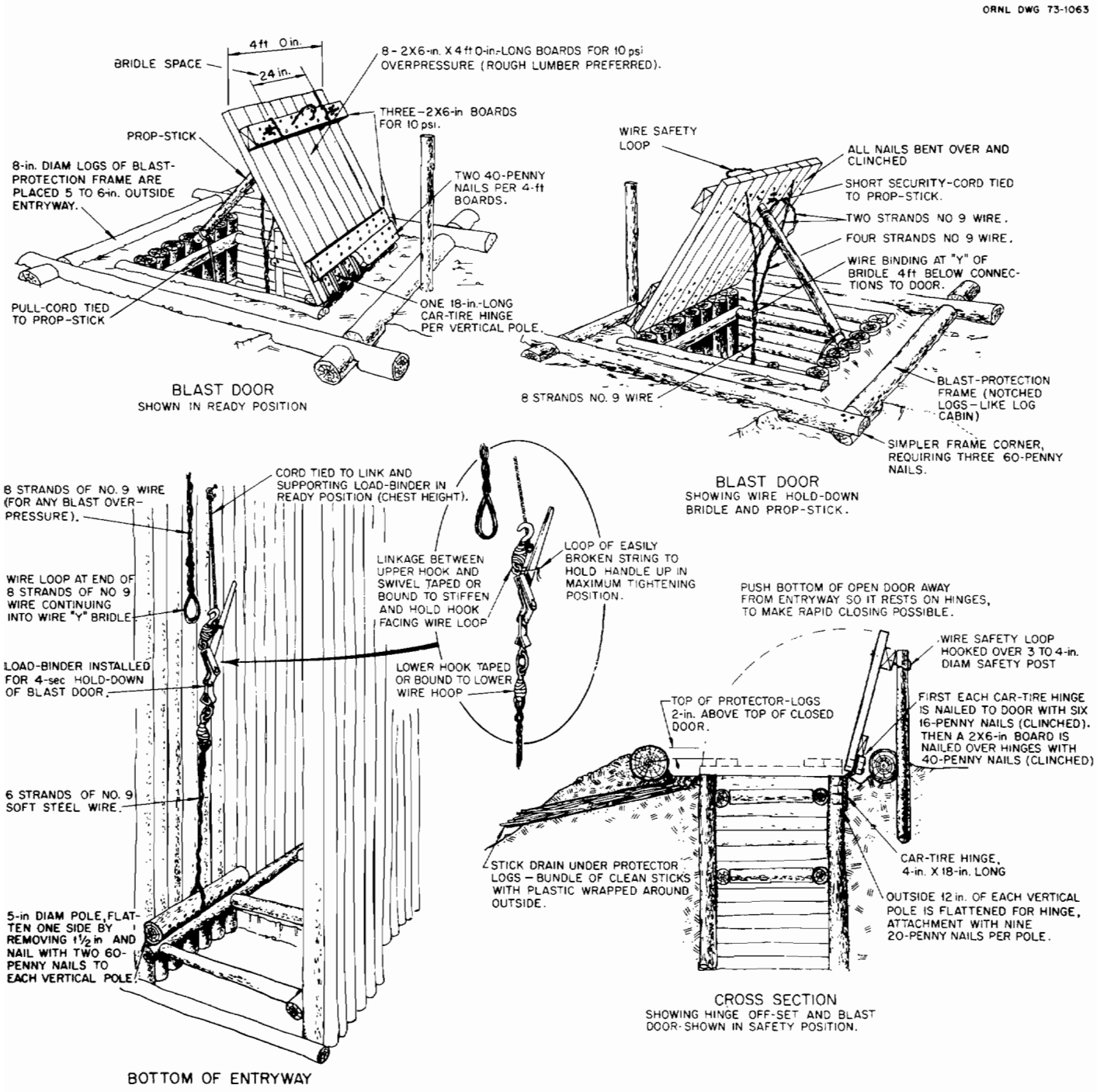


Fig. D.14. Expedient blast door that can be closed and secured in 4 seconds.

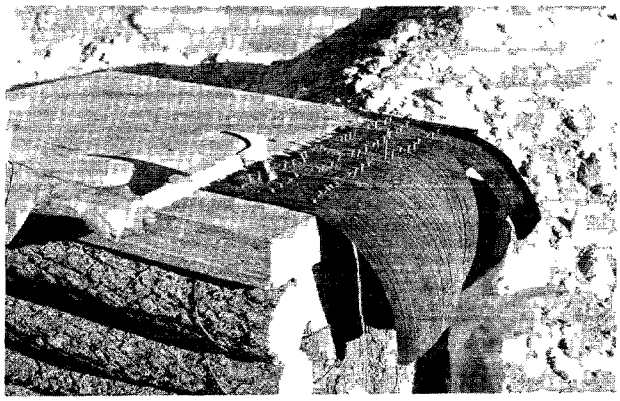


Fig. D.15. Tire-strip hinges nailed to an expedient, 4-inch-thick blast door made of plywood, designed to withstand 50-psi blast effects of very large weapons and undamaged by blast at the 53-psi range.

Fig. D.16. Blast-tested triangular blast door made of hand-hewn pine poles, notched and nailed together. This door closed on a triangular pole base that is concealed in this photo by two of the three blast-protector logs that also withstood 53-psi blast effects.

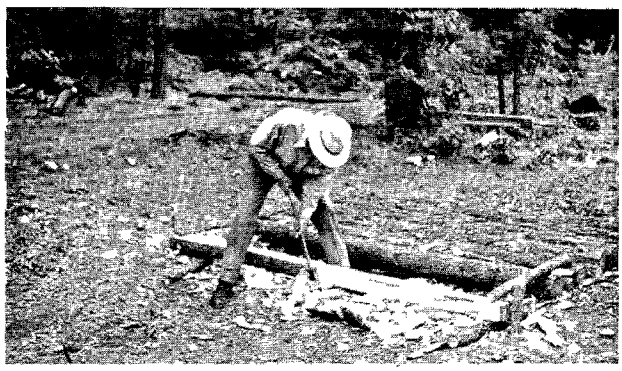


Fig. D.17. Hewing flat sides on a pole with a sharp ax.

To hew a second flat side at right angles to the first side, rotate the pole 90°, secure it again, and repeat—as pictured in Fig. D.17.

- **Provide blast closures for an adequate ventilation system.** The following two expedient closure systems permit adequate volumes of ventilating air to be pumped through a shelter:

1. **Install two blast doors,** one on each end of the shelter, designed to be left open until the extremely bright light from a large blast is seen. Figure D.14 shows a door held open by a prop-stick that can be yanked away by the attached pull-cord. While propped open, one blast door serves as an extremely low-resistance air-intake opening, and the other serves as an air-exhaust opening. A large KAP can pump air at the rate of several thousand cubic feet per minute through such open doors.

When an attack is expected, each pull-cord should be held by a shelter occupant who stays ready at all times to yank out the prop-stick as soon as he sees the light of an explosion. After the door has fallen closed, the loop at the end of its wire bridle is close to the upper hook of the load-binder and at the same height (Fig. D.14). The person who closes the door should quickly hook the upper hook of the load-binder into the wire loop and pull down on the handle of the load-binder. The door will then be tightly shut. (Sources during an emergency would be the millions of load-binders owned by truckers and farmers.)

At distances from a large explosion where blast wave and overpressure effects are not destructive enough to smash most good expedient blast shelters, there is enough time between the instant the light of the explosion is seen and the arrival of its blast wave for an alert person to shut and securely fasten a well-designed blast door. The smaller the explosion and the greater the overpressure range, the shorter the warning time. Thus at the 15-psi overpressure range from a 1-megaton surface burst (1.5 miles), the blast wave arrives about 2.8 seconds after the light; whereas at the 10-psi overpressure range from a 1-megaton surface burst (1.9 miles), the blast wave arrives about 4.5 seconds after the light. For a 20-megaton surface burst, the warning time at the 15-psi range is about 8 seconds, and at the 30-psi overpressure range, about 4 seconds. Experiments have shown that even people who react quite slowly can close and secure this door within 4 seconds after seeing a spotlight shine on the door without warning.

2. **Install in the vertical entries two expedient blast valves,** one on each end of the shelter, to protect both the vertical air-intake and air-exhaust ducts, which should be installed outside the vertical entries. Figure D.18 illustrates the construction of a fast-closing expedient blast valve, a design that was undamaged by the 65-psi shock wave and other effects produced by the explosion of a million pounds of TNT. When blast-tested in a shock-tube at 100-psi, the flaps were undamaged; they closed in 6/1000 of a second (0.006 sec.). This is as fast as the best factory-made blast valves close.

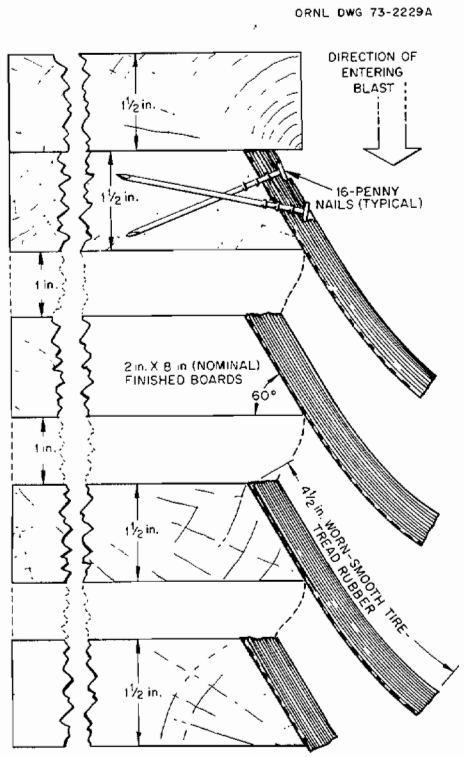


Fig. D.18. Overlapping-Flaps Blast Valve, made of boards, plywood, and strips cut from the treads of worn car tires.

To withstand 50 psi, the load-bearing "2-inch" boards (actually $1\frac{1}{2}$ inches thick) of the valve should be at least 6 inches wide, if the 1-in.-high air openings are each made 12 in. wide, measured between two vertical poles of a shelter entry. See Fig. D.19, that gives the dimensions of a valve that has been blast tested.[5] Note that there are 5 inches of solid wood at each end of each 1-in.-high air opening. If there are 5 such air openings to a valve, a properly installed KAP (Appendix B) can pump air at about 125 cubic feet

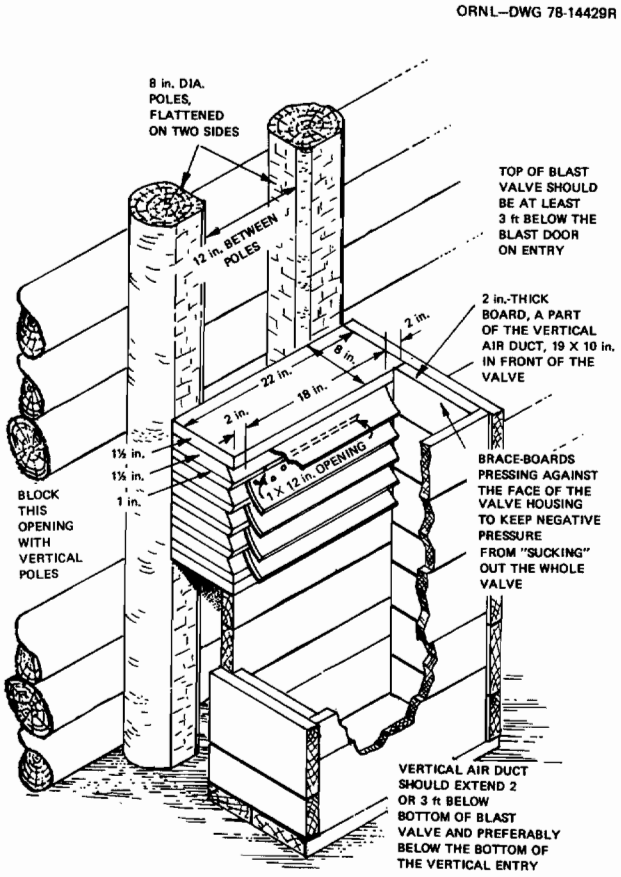


Fig. D.19. Installation of a 50-psi Overlapping-Flaps Blast Valve in such a way that it will not be blown into a shelter by the blast overpressure, nor pulled out by the following negative pressure ("suction") phase.

per minute (125 cfm) through a shelter equipped with such valves. This ventilation rate is ample for at least 40 people in cold weather. Except in hot and humid weather, a constant air supply of about 10 cfm per shelter occupant is enough to maintain tolerable conditions during continuous shelter occupancy for many days.

If a factory-made blower capable of pumping several hundred cfm is available, use it. Such a hand-operated blower can pump against much higher air flow resistances than a KAP can. It can pump its full-rated volume of outdoor air through a shelter equipped with two Overlapping-Flaps Blast Valves—each with only 2 air openings—providing 24 square inches of openings per valve.

Remember that a pressure of 7200 pounds pushes against each square foot of the exposed face of

a blast valve when it is subjected to a 50-psi blast overpressure. Also keep in mind that the "suction" that follows can exert an outwardly directed force of up to 700 pounds per square foot on the valve face and can yank it out of position unless it is securely installed. Figure D.19 shows how to securely install a blast valve. (Merely nailing a blast valve in its opening will not enable it to withstand severe blast forces.)

- **Minimize aboveground construction and the mounding of shielding earth.** At high overpressure ranges, the shock wave and the blast-wind drag can wreck an aboveground shelter entry. For example, the 5-ft-high earth mound over a shelter built with its pole roof at ground level was moved enough by 1-kiloton air-blast effects at the 53-psi overpressure range to break one of the poles of a blast-door frame. The forces of a 1-megaton explosion at the same overpressure range would have operated 10 times as long, and probably would have smashed the vertical entryways of this shelter. Whenever practical, a blast shelter should be built far enough belowground so that the top of its shielding earth cover is at ground level. Avoiding aboveground construction and earth mounds also greatly reduces the chances of damage from blast-hurled, heavy debris, such as tree trunks and pieces of buildings.

Dry earth, steeply mounded over a shelter which is subjected to blast winds from a big explosion, will be mostly blown away. However, blast-wind "scouring" of **wet** earth is negligible. The blast winds from a 1-kiloton explosion at the 31-psi overpressure range scoured away 17 inches of **dry,** sandy soil mounded at a slope of 32°.

If it is impractical to build a blast shelter with its roof belowground, good protection can be attained by mounding even dry earth at slopes not steeper than 10°.

- **Provide adequate shielding against initial nuclear radiation.** Good expedient blast shelters require a greater thickness of earth cover than is needed on good fallout shelters, for these reasons:

  * Blast shelters should also protect against initial nuclear radiation emitted by the fireball. This radiation is reduced by half when it penetrates about 5 inches of packed earth (as compared to a halving-thickness of only about $3\frac{1}{2}$ inches of earth against radiation from fallout).
  * The initial radiation, in some areas where good blast shelters will survive, can be much greater than the fallout radiation is likely to be.
  * Initial nuclear radiation that comes through entryways is more difficult to attenuate (reduce) than fallout radiation. Therefore, longer entryways or additional right-angle turns must be provided.

For these reasons, good blast shelters should be covered with at least 4 ft of well-packed, average-weight earth, or 5 ft of unpacked or light earth. (A 3-ft thickness gives excellent protection against radiation from fallout.)

A 50-PSI SMALL-POLE SHELTER

This expedient blast shelter is described in detail to enable the reader to build this model. The details will help him better understand the design principles of other expedient blast shelters that are capable of preventing injuries from blast effects severe enough to destroy all ordinary buildings and kill the occupants. Blast tests and calculations have indicated that the Small-Pole Shelter described and illustrated in Appendix A.3 will afford protection against all weapon effects at overpressure ranges up to 50 psi that are produced by an explosion of 1 megaton, or *larger,* provided the shelter is:

- Made with horizontal entryways each with ceilings no higher than 7 ft, 2 in., no wider than 3 ft, and each at least 10 ft long—to lessen the radiation coming through the entries (see Fig. D.20). Lower and narrower entryways would give better protection but would increase the time required for entry.

- Constructed with a floor of poles that are 4 in. or more in diameter, laid side-by-side, with the wall poles resting on the floor poles. The ground shock and earth pressures at a depth of 10 ft or more resulting from an overpressure on the surface of more than about 35 psi, if caused by a large explosion, may destabilize and squeeze earth upward into the shelter through an unprotected earth floor. The Small-Pole Shelter described in Appendix A.3 has an earth floor.

- Installed in an excavation about 13 feet deep, with the shelter's vertical entrances appropriately increased in height so that the blast doors are only about one foot above the original ground level.

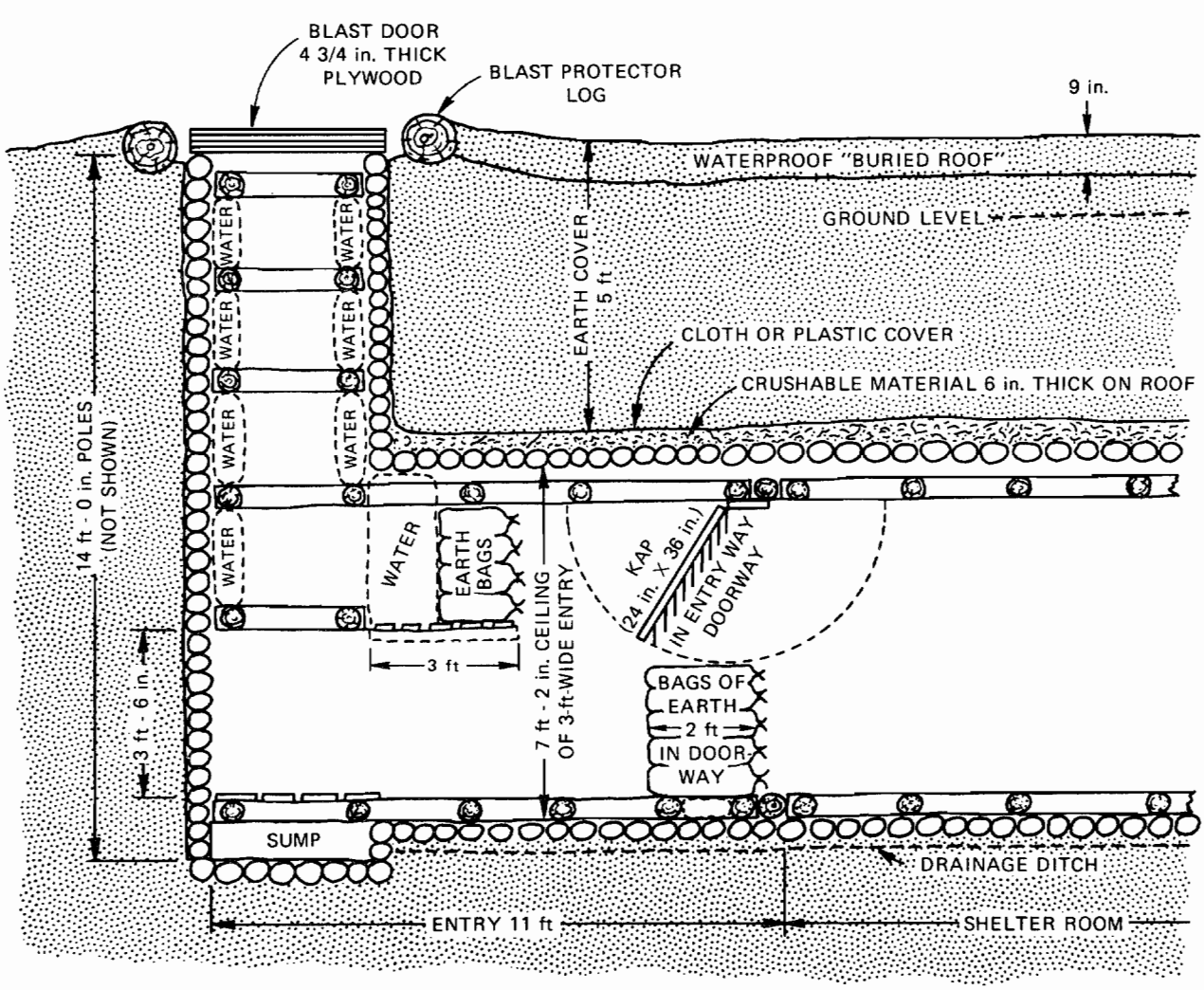


Fig. D.20. Entryway of Small-Pole Blast Shelter shielded against initial nuclear radiation. This sketch is a simplified vertical section through the centerline of one end of the shelter.

- Made with 4 rectangular horizontal braces in each vertical entry, in addition to the ends of the two long, ladder-like braces. The detailed drawings in Appendix A show such braces. The lowest rectangular brace should be positioned $3\frac{1}{2}$ feet above the flooring at the bottom of the vertical entry (see Fig. D.20).

- Equipped with blast doors each made of 5 sheets of $\frac{3}{4}$-inch exterior plywood (see Fig. D.15) bonded with resin glue and nailed together with $4\frac{1}{2}$ in. nails. The nails should be driven on 4-in. spacings and their protruding ends should be clinched (bent over). The blast doors must be secured against being yanked open by negative pressure ("suction") by securing them with a strong wire bridle (see Fig. D.14), and with the lower, fixed wire strongly connected near the bottom of the entry to all of the vertical poles on one side, as shown in Fig. D.14.

- Provided with an adequate ventilation pump and with ventilation openings protected against blast by expedient blast-valves (Fig. D.18) installed in the vertical entries as shown in Fig. D.19, to protect the air-intake and the air-exhaust openings. (Ventilation openings should be as far as practical from buildings and combustible materials. Manually closed ventilation openings are NOT effective at the 50-psi overpressure range of most weapons, because there is insufficient time to close them between the arrival of

the warning light from the explosion and the arrival of the blast wave.)

- Made with the roof poles covered by a yielding layer of brush or limbs about 6 inches thick, or of innerspring mattresses. This yielding layer in turn should be covered with bedsheets or other strong cloth, to increase the effectiveness of protective earth arching. Brush or limbs should be laid in 3 layers with sticks of the middle layer perpendicular to those of the other two layers.

- Covered with 5 feet of earth, sloped no steeper than 10°.

- Provided with additional shielding materials in the entryways, as shown in Fig. D.20. Such shielding would be needed to prevent occupants from receiving possibly incapacitating or fatal doses of initial nuclear radiation through the entryways at the 50-psi overpressure range, if the shelter is subjected to the effects of a weapon that is one megaton, *or larger,* in explosive yield.

Damp earth serves better for neutron shielding material than dry earth and can be substituted for water as shielding material if sufficient water containers are not available. (At the 50-psi overpressure range from explosions *smaller* than one megaton, the entry and shielding shown in Fig. D.20 may not provide adequate protection against initial nuclear radiation.)

When the shelter is readied for rapid occupancy, the shelter-ventilating KAP is secured against the ceiling, and the bags of earth in the doorway (under the KAP) are removed. Persons entering the shelter would stoop to go under the platform adjacent to the vertical entry. This platform is attached to vertical wall-poles of the horizontal entry and supports shielding water and earth. When all except the person who will shut and secure the blast door are inside the shelter room, occupants should quickly begin to place bags of earth in the doorway. When the attack has begun, the whole doorway can be closed with bags of earth or other dense objects until ventilation is necessary.

The entries of other types of blast shelters can be shielded in similar ways.

- Protected against fire by being built sufficiently distant from buildings and flammable vegetation and by having its exposed wood covered. For maximum expedient protection against ignition by the thermal radiation from a large explosion, all exposed wood should be free of bark, coated with wet mud or damp slaked lime (whitewash), and covered with aluminum sheet metal or foil to reflect heat. (Most of the thermal radiation from an explosion that was 1 megaton or larger would reach the 50-psi overpressure range after the blast wave had arrived and had torn the expedient protective coverings from the wood. However, as has been observed in megaton nuclear weapon tests, the dust cloud first produced by the popcorning effect and later by the blast winds would screen solid wood near the ground so effectively against thermal radiation that it would not be ignited, provided it had been initially protected as described above.)

PRECAUTIONS FOR OCCUPANTS OF BLAST SHELTERS

Although a well constructed blast shelter may be undamaged at quite high overpressure ranges, its occupants may be injured or killed as a result of rapid ground motions that move the whole shelter several inches in a few thousandths of a second. Rapid ground motions are not likely to cause serious injuries unless the shelter is in an area subjected to 30-psi or greater blast effects. To prevent possible injury, when the occupants of high-protection blast shelters are expecting attack they should avoid:

- Having their heads close to the ceiling. The "air slap" of the air-blast wave may push down the earth and an undamaged shelter much more rapidly than a person can fall. If one's head were to be only a few inches from the ceiling, a fractured skull could result.

- Leaning against a wall, because it may move very rapidly, horizontally as well as vertically.

- Sitting or standing on the floor, because ground shock may cause the whole shelter (including the floor) to rise very fast and injure persons sitting or standing on the floor. The safest thing to do is to sit or lie in a securely suspended, strong hammock or chair, or on thick foam rubber such as that of a mattress, or on a pile of small branches.

In dry areas or in a dry expedient shelter, ground shock may produce choking dust. Therefore, shelter occupants should be prepared to cover their faces with towels or other cloth, or put on a mask. If an attack is expected, they should keep such protective items within easy reach.

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